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Socially relevant and inclusive operations management

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Abstract

Many parts of the world are experiencing extreme weather events, energy poverty, food insecurity, and lack of access to basic healthcare. Moreover, concerns over socioeconomic, gender, and racial inequalities are growing. These socially relevant issues are ripe for analysis and improvement using an operations management lens. In this paper, we review some of the relevant research advancements made in the last decade, and identify future research directions on these important topics. In particular, we focus on papers related to sustainable planet (renewable energy, environmentally and socially responsible operations, regulation-driven operations), agriculture, and public health. For future research directions, we discuss the role of innovative business models and disruptive technologies, such as artificial intelligence (AI) and blockchain, in addressing these pressing issues.

KEYWORDS

access to healthcare, agriculture, climate change, equity, food security, inclusive operations, renewable energy, socially responsible operations, sustainable operations

1 | INTRODUCTION

Extreme climate change, global food shortage, lack of basic healthcare, increasing inequality, and growing digital divide are often cited as major challenges for humanity in the upcoming decades. The United Nations' sustainable development goals (SDGs), which are displayed in Figure 1, list 17 goals out of which 10 relate to the above challenges. These socially relevant issues are ripe for analysis and improvement using an operations management lens. As a result, there is a growing interest on these topics, see, for example, Deshpande and Swaminathan (2020), Lee (2021), Lee and Tang (2018), Netessine (2021), and Swaminathan and Deshpande (2020). In this paper, our aim is to highlight some of the relevant research advancements made in the last decade, and identify opportunities for future research and innovations on these important topics. In particular, we will focus our attention on papers related to sustainable planet, agriculture, and public health. We will also emphasize the stream of work that contributes to inclusive operations management.

2 | SUSTAINABLE PLANET

Early research in sustainable operations was about topics such as remanufacturing (Atasu et al., 2008; Debo et al., 2005; Ferguson & Toktay, 2006; Ferrer & Swaminathan, 2006; Galbreth & Blackburn, 2006; Kekre et al., 2003; Örsdemir et al., 2014), reverse logistics (Guide & Wassenhove, 2009), and ISO 14000 certification (Albuquerque et al., 2007). See, for example, Kleindorfer et al. (2005) and Tang and Zhou (2012) for reviews of earlier research. More recent research has primarily focused on three areas—renewable energy, environmentally and socially responsible operations management, and regulation-driven operations management. Below, we will discuss these developments in the last decade.

2.1 | Renewable energy and smart technology

Power generation is the largest contributor of emissions in the world (International Energy Agency, 2021). In the United States, electricity generation is responsible for 25% of emissions, making it the second largest source of emissions (US EPA, 2021). Thus, innovating and decarbonizing power sector is essential to "take urgent action to combat climate change and its impacts" (SDG.13) and to "ensure access to affordable, reliable, sustainable and modern energy for all" (SDG.7). Operations management researchers have made important progress toward these goals by studying key challenges and opportunities in the energy sector.

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FIGURE 1 United Nations' sustainable development goals. *Source*: UNESCO (2021) [Color figure can be viewed at wileyonlinelibrary.com]

Careful design of retail electricity rates is crucial for responsible energy consumption and shaving the peak load. These two may significantly reduce the reliance on emission-intensive generation technologies (e.g., oil-fired power plants) during peak periods, saving the environment. The operations management community has analyzed some of the key innovations on that front. A technology that enables innovative retail rate design is smart meter—a device that enables two-way frequent communication between electric utilities (*utilities*) and end users. The landscape of the electricity sector is changing with the wide deployment of smart meters, which provide vast amount of data to utilities. This change is also strongly supported by policy makers in the European Union and the United States (Federal Energy Regulatory Commission, 2019; The E.U., 2019). In this context, Keskin et al. (2020) study data-driven clustering of customers as well as feature-based dynamic pricing of retail electricity, and utilize real-life smart meter data in the case study. Apart from smart meters, there are other important developments in practice such as incentive contracts for end users or time-of-use pricing. Fattahi et al. (2019) design direct load contracts to incentive customers to reduce their electricity consumption during peak load period. Webb et al. (2019) study the potential value of coordinating energy-efficiency initiatives with demand response contracts. Choi et al. (2020) and Kök et al. (2018) compare and contrast the flat price with time-of-use pricing in different contexts.

In decarbonizing the grid, renewable energy investments are as important as smart retail rate design. Investment in small-scale renewable energy technologies (e.g., rooftop solar panels) has skyrocketed in the last decade. According to U.S. EIA (2021), small-scale solar PV capacity increased by nearly sixfolds from 2014 and 2021. With these distributed renewable energy (DRE) technologies, electricity end users reduce their reliance on utilities by generating their own electricity while contributing to the environment. Policy makers implemented various support mechanisms to boost the DRE capacity. Thus, it is of utmost importance to understand how DRE support policies influence utility profits and social welfare. In the United States, a key DRE support mechanism is the net-metering policy, which is mandatory in the vast majority of United States (DSIRE, 2022a). Under net metering, the utility must buy back excess generation of its customers (with DRE technology) at a particular rate. There has been strong push against net-metered solar by utilities. The rationale is that net-metered DRE is believed to hurt the utility bottomline because it is typically more expensive to buy the excess generation of net-metered customers than to obtain the same amount from traditional sources. However, Sunar and Swaminathan (2021) show that net-metered distributed solar could be a positive for utilities because of the interaction between net-metered DRE and wholesale market; but this positive impact is valid only when solar panel adoption is below a certain threshold. Mamaghani and Cakanyildirim (2021) find that when net-metered solar is a negative for utilities, it can be addressed by carefully designing the retail electricity rate. Taking the perspective of electricity end users, Singh and Scheller-Wolf (2022) establish that retail electricity prices must differ based on usage and solar panel adoption status to achieve socially desirable outcomes. Apart from regulation, it is also important to analyze end users' solar panel adoption strategy and how it influences the operations of solar companies. Angelus (2021) analyzes the timing of small-scale DRE investments, the resulting DRE capacity addition, and the consecutive impact on the electricity price. Agrawal et al. (2022) find that for a solar company, selling solar panels (respectively, offering non-ownership benefits of solar panel) is more favorable when the investment (respectively, generation) subsidy is high.

Apart from DRE technologies, there has been a boost in the large-scale renewable energy investments, as well. Major investors include utilities, independent power producers, and large corporations. Utilities' renewable energy investments are mainly driven by renewable portfolio standards (RPS), which is part of Clean Energy Standard in some states. Currently, there are 30 states with RPS in the United States (DSIRE, 2022b). According to this policy, utilities are required to obtain certain fraction of their power supply from renewable energy sources. For example, in California, 60% of retail electricity sales must come from renewable energy resources by 2030 (CPUC, 2022). Operations management researchers have taken important steps to analyze key opportunities and challenges for large-scale renewable energy generation. Hu et al. (2015) demonstrate that the granularity of demand and renewable energy output matters in renewable investment decisions. Alizamir et al. (2016) study the design of feed-in-tariff programs for renewable technologies, and identify the conditions under which constant profitability policy is optimal. Aflaki and Netessine (2017) find that increasing the emissions cost can decrease the share of renewable capacity investments by utilities in an energy investment portfolio. Al-Gwaiz et al. (2017) show that introducing prioritized renewable energy can exacerbate the intensity of market competition. Sunar and Birge (2019) study renewable energy producers' strategic participation in wholesale markets. They find that increasing an undersupply penalty rate to improve the accuracy of renewable energy production commitments in wholesale markets might unintendedly cause reduced reliability and inflated production commitments by renewable power producers. Peura and Bunn (2021) investigate how prioritizing renewable energy affects the electricity price when there is a forward market, and show that renewable energy might lead to an increase in the wholesale prices.

2.2 | Firms' voluntary actions for environmental and social responsibility

In the past decade, researchers have studied various important problems in firms' environmentally and socially responsibility operations management. A stream of this literature studies the design and drivers of firms' responsible practices (e.g., responsible sourcing, voluntary carbon offseting strategies, and substance replacement). Caro et al. (2013) study the emissions allocation among supply chain members and show that overallocation of emissions is necessary to motivate firms to exert the optimal effort in emissions reduction. Kraft et al. (2013) examine a firm's replacement strategy when a substance in its products is potentially hazardous. They find that developing a replacement substance is desirable for the firm when there is a regulation risk. Sunar & Plambeck (2016) analyze a supply chain with a coproduct supplier, and show that a buyer voluntarily offseting its entire supply chain emissions can be a win–win for the buyer and the environment. The authors verify their analytical findings with real-life data from rare earth and palm oil supply chains. Agrawal and Lee (2019) show that in order to motivate the supplier(s) to adopt a sustainable process, a sustainability requirement (respectively, preferable sustainability) in procurement is effective when there is a single supplier (respectively, multiple suppliers). Orsdemir et al. (2019) conclude that vertical integration may be necessary to ensure corporate social responsibility. Villena (2019) explains why firms fail in passing the sustainability compliance requirement from one tier to another in a supply network, and finds that the procurement is the key enabler of successful propagation of sustainability compliance over the supply network. Huang et al. (2020a) investigate how the supplier diversity impacts companies' voluntary emission reduction strategies, and show that knowledge sharing significantly reduces the emission intensity, and locational and sectoral diversity have different effects. Caro et al. (2021) find that the historical level of unauthorized subcontracting and likelihood of future unauthorized subcontracting are highly related. Gopalakrishnan et al. (2021) design a scheme to allocate total supply chain emissions among supply chain members, and show that the proposed allocation has various features suitable for practical implementation. Analyzing the carbon disclosure project data, Blanco (2021) conclude that measuring Scope 3 emissions is associated with the change in the content and the format of the firm disclosures. Gao and Souza (2022) study a firm's voluntary carbon offsetting strategy in the presence of environmentally sensitive customers, and show that the offset prices should generally be low, but, in some cases, high offset prices are more beneficial to the environment. Huang et al. (2022) study the equilibrium social responsibility efforts of firms in a multitier supply chain, and show that the buyer either exerts no effort or chooses to directly control or delegate.

Another stream of this literature studies auditing strategies for environmental or labor practices. Kim (2015) finds that a set inspection schedule could be more preferable than random inspections. Plambeck and Taylor (2016) identify the conditions under which buyers' increased corporate responsibility efforts lead to more cheating or less care by the supplier. Wang et al. (2016) characterize the regulator's optimal environmental inspection and reward policy under which the firm receives a reward when it voluntarily discloses its environmental violation. Chen & Lee (2017) find that the supplier certification is more effective than process audit and contingency payment to differentiate among suppliers with different responsibility risks. Considering global supply chains, Cho et al. (2019) find that when inspection is not effective in reducing the child labor, increasing wholesale price (and the appropriate inspection strategy) can reduce it. Chen et al. (2020) show that although buyers auditing the common supplier improves aggregate buyer profit, downstream competition decreases the buyers' incentive to audit this key supplier. This disincentive is eliminated when the buyers cooperatively audit the suppliers at a fairly shared cost. Short et al. (2020) conclude that suppliers improve the labor conditions more when the audit timing is known and/or when the auditors are well trained. Zhang et al. (2022) identify the optimal dynamic auditing policy for the buyer in a supply chain network. Accordingly, under the optimal policy, the buyer first audits to eliminate noncomplying suppliers, and then, they either stop auditing or audits to rectify the supplier.

Supply chain visibility/transparency is an important topic in this literature, as well. Kraft et al. (2018) examine the effect of supply chain visibility on customers' evaluation of company's social responsibility efforts, and show through experiments that greater visibility is valued by customers. Chen et al. (2019) analyze the buyer's disclosure strategies of its supplier list to improve the responsibleness of their supplier's operations. The authors find that the buyer is more inclined to reveal the list when suppliers incur a larger penalty for a violation or when NGO's auditing risk is higher.

Finally, there is an empirical literature that investigates how socially responsible practices impact key performance metrics for firms. Jacobs (2014) studies the relationship between voluntary emissions reduction announcements and the shareholder value. The author concludes that the market became less responsive to voluntary emission reduction announcements during the studied time period. Li and Wu (2020) find that public and private firms significantly differ in terms of the real impact of their corporate social responsibility actions. Jacobs et al. (2016) conclude that when the firms have low productivity, corporate social responsibility efforts have minimal effect on financial performance; these efforts can be effective only when operational productivity is sufficiently high.

For other reviews and discussions in sustainable/responsible operations, please see Girotra and Netessine (2013), Lee and Tang (2018), Sodhi and Tang (2019), Van Wassenhove (2019), Kalkanci et al. (2019), and Swaminathan and Deshpande (2020).

2.3 | The effect of environmental regulations on firms' operations

While some of firms' efforts for sustainable planet are voluntary (as discussed in Section 2.2), the others are driven by regulations (e.g., the European Union Emissions Trading System, carbon tax, and waste regulations). Operations management researchers have made important contributions to understand how firms would or should operate under climate change regulations, including carbon tax and cap-and-trade (Anand & Giraud-Carrier, 2020; Cachon, 2014; Drake et al., 2016; Huang et al., 2021; Krass et al., 2013; Park et al., 2015; Sunar & Plambeck, 2016; Sunar, 2016) and waste and recycling regulations (Atasu & Subramanian, 2012; Dhanorkar & Muthulingam, 2020; Esenduran et al., 2017; Gui et al., 2016).

3 | AGRICULTURE

Agriculture is one of the critical sectors as it directly impacts the food industry, and creates significant value for the economy. In 2019, the U.S. agriculture sector generated \$136.1 billion in value. The combination of U.S. agriculture, food, and related industries generated more than \$1.1 trillion, which constituted 5.2% of the U.S. gross domestic product (GDP) in 2019 (USDA, 2021). In developing countries, agriculture is the key income generator for a considerable portion of population, and the economy heavily relies on agriculture, more so than developed countries. In 2020, agriculture contributed to more than 15% of the GDP for many developing countries (The World Bank, 2021a).

Operations management researchers have studied various farming problems in developing countries where a large portion of farmers are smallholders. These studies contribute to SDG 2 that aims to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture."

3.1 | Inclusive agriculture: Helping farmers in developing countries

A key research topic in this stream is contract farming, which is an important practice in developing countries. Huh and Lall (2013) study a farmer's decisions in allocating the land among multiple crops varying in irrigation needs, and allocating the irrigation water among crops. They develop two formulations and examine the implications of farmer's decisions by using data from India. Federgruen et al. (2019) take a supply chain perspective on contract farming and study a manufacturer's design of its agricultural supplier network, which involves farmer selection and contract menu design decisions by the manufacturer. The authors propose two solution methods for the manufacturer, and investigate their implications by using a smallholder farmer data set from India. de Zegher et al. (2019) study the choice of sourcing channels and contract design in an agricultural value chain where the supplier can adopt an innovative technology. They find that a particular cost elasticity of the technology is the key determinant of these choices to design a both responsible and profitable sourcing strategy. Chen and Chen (2021) show that introducing contract farming for high-value agriculture (HVA) products improves the incomes of both contract and noncontract farmers while it might widen the income disparity between contract and noncontract farmers.

There are several papers that study information/knowledge sharing problems in this stream. Tang et al. (2015) study whether using market information or following agricultural advice improves farmers welfare more in developing countries, and find that while the former always improves farmers' welfare, the latter could reduce it. Chen et al. (2015) investigate peer-to-peer knowledge sharing dynamics in a platform where farmers post their questions related to farming. The authors show that in equilibrium, the knowledgeable (core) farmer's answers are always less informative than the expert's in the platform. Hu et al. (2019) analyze the behaviors of strategic and naive farmers for planting, and how they influence production, price fluctuations, and social welfare. The authors find that having some strategic farmers can increase the social welfare, relative to the case with only naive farmers.

Apart from these topics, operations management researchers examine many other important aspects of the farming problems in developing countries. Dawande et al. (2013) study the equitable distribution of the surface water among farmers who vary in their access to water in developing countries. They design a mechanism and demonstrate its efficiency and effectiveness. An et al. (2015) find that a smallholder farmer is better off with joining into an aggregation (e.g., cooperative) only if the aggregation is sufficiently small sized. Devalkar et al. (2018) discuss current applications of data science and information sharing in Indian agriculture, and explain opportunities in this context. Zhang and Swaminathan (2020) analyze the optimal seeding policy for farmers who rely on rain for agriculture, and conduct numerical studies based on data from South Africa. The authors design a well-performing seeding heuristic, and establish that as the climate gets more undesirable for farming, commonly used practical heuristics perform worse relative to the optimal policy. Levi et al. (2020) design and implement a two-stage auction in an online agriplatform for smallholder farmers in Karnataka, India. The authors show that the implementation results in a price increase of 3.6%. Yi et al. (2021) examine different financing methods for a smallholder farmer in a developing country, and identify the conditions under which the farmer or the intermediary platform prefers each financing method. Chintapalli and Tang (2022) examine how different support mechanisms for farmers—cost subsidy and credit-based minimum support price (MSP)—influence production, farmer's and consumer's surpluses. They find that cost subsidy leads to lower surplus for the farmer than MSP.

3.2 | Other key developments in the agricultural operations literature

Apart from the farmers' problems in developing countries, operations management researchers have analyzed various other key problems in the agricultural sector. Alizamir et al. (2019) compare the two farming subsidy programs in the United States, that is, price loss coverage (PLC) and agriculture risk coverage (ARC), and show that relative to the case with no subsidy, PLC increases planted acres while ARC may decrease it, reducing the crop supply. Boyabatlı et al. (2019) analyze the dynamic allocation of farmland among multiple crops, and find that dedicating the farm to a single crop decreases the farmer's profit relative to implementing sustainable agriculture based on crop rotation. Studying a setting where farmers are exposed to yield, quality, and market price uncertainties, Ayvaz-Çavdaroğlu et al. (2021) show that the farmers underinvest in the crop quality when they are compensated based on the market price. Levi et al. (2022) analyze two governmental interventions used to mitigate the artificial shortage of agricultural products: cash subsidy for consumers and increasing product availability (with imports). The authors show that the cash subsidy can exacerbate the shortage whereas increasing product availability typically mitigates it. Dong (2021) provides a review and discusses some challenges related to agricultural supply chains.

4 | INCLUSIVE HEALTH

4.1 | Increasing access to healthcare

Health is essential to human well-being. It is also critical for economic development because it directly impacts the quality of education and work. Yet, more than half the world, that is, five billion people, are estimated to lack access to healthcare services by 2030 (The World Bank, 2021c). This pressing global issue is emphasized in the U.N.'s SDG 3 that aims to "ensure healthy lives and promote well-being for all at all ages." Because healthcare expenses push almost 90 million people into poverty every year, health is also directly linked to the U.N.'s SDG 1 that aims to "end poverty in all its forms everywhere" (The World Bank, 2021c). Researchers in operations management have analyzed important problems aiming to improve vulnerable populations' access to healthcare, medical supply, or equipment. In these situations, the most important issues relate to the allocation of scare resource in the most efficient, effective, and equitable fashion (Kaplan & Merson, 2002; Swaminathan, 2003; Zenios et al., 2000).

The majority of the recent literature focuses on inventory management strategies of not-for-profit organizations in a humanitarian setting. Natarajan and Swaminathan (2014) study the multiperiod inventory management of a humanitarian health organization with limited funds, and establish that the optimal policy is state independent and easy to implement. The authors also investigate how the uncertainty and variability in funding affect the organization's operations, and show that timely but partial funding might be more favorable than delayed full funding. Atasu et al. (2017) analyze the operations of medical surplus recovery organizations (MSROs) that provide medical surplus to disadvantaged healthcare facilities in developing countries. The authors show that sharing the MSRO's inventory information with potential recipients may lead to inefficient ordering strategies, and they propose some remedies for this problem. Gallien et al. (2017) analyze data to understand the reasons for the stockouts of critical drugs in Africa albeit significant international donations for the purchase of medical products. The authors conclude that stockouts are because of the uncertainty in fund disbursements and grant monitoring frequency. Natarajan and Swaminathan

(2017) develop well-performing heuristics for humanitarian inventory allocation among patients with different health states under funding constraints when multiple doses of the resource need to be given to a patient. Zhang et al. (2020) design an implementable mechanism to improve inventory management strategies of MSROs. Motivated by the food distribution problem to save lives in war-affected areas, Park and Berenguer (2020) examine a humanitarian organization's inventory allocation problem among multiple demand locations under supply constraints, and propose an objective function that considers both efficiency and fairness.

There are also studies that analyze incentive designs to improve access to care. Mehrotra and Natarajan (2020) study an incentive design problem to improve the healthcare usage of patients in developing countries. They find that providing the right mixture of supply- and demand-side incentives is more effective than offering only supply- or demand-side incentives. Arora et al. (2021) examine how Child Care Resource and Referral agencies should allocate their funds among different activities to provide an equitable distribution of monetary support for low-income families who cannot afford child care. Niewoehner and Staats (2022) show that providing performance feedbacks to clinics can be effective in improving clinics' vaccination rates for influenza.

There is a stream of research that studies business models for healthcare access. A business model that can increase access to healthcare is shared medical appointments under which patients receive care in batches. Buell et al. (2021) study whether this model is advantageous in terms of customer engagement. Gernert et al. (2022) analyze innovative business models related to ambulance systems in developing countries, and show that a provider-only business model might not be desirable for patients.

Value chain design is key in improving access to healthcare. In this context, McCoy and Lee (2014) analyze the allocation problem of a humanitarian organization's resources among multiple health clinics. They study the magnitude of improvement with the additional humanitarian capacity, and conduct a case study based on data from Zambia. Stauffer et al. (2015) formulate the global vehicle supply chain design problem of a humanitarian organization, and find that having both a centralized hub (with minimal vehicles) and the capability of capacity expansion through temporary hubs can considerably reduce supply chain costs. Jónasson et al. (2017) develop an optimization and simulation framework to reduce delays in diagnosing the human immunodeficiency virus (HIV) among infants in sub-Saharan Africa. Using data from Mozambique, the authors demonstrate that relative to the current practice, the average sample turnaround time for diagnosis significantly decreases when labs are optimally assigned to clinics. Mills et al. (2018) study how to allocate patients to medical facilities and how to allocate ambulances to patients after a disaster when the number of ambulances is limited. Bhimani and Song (2016) and Besiou et al. (2021) discuss potential contribution areas for operations research (OR)/management science (MS) researchers in humanitarian operations.

4.2 | Food security

Food is an indispensable part of human life. Yet, nearly 33% of people in the world did not have access to sufficient food in 2020 (U.N., 2022). The food insecurity is not specific to developing countries or conflict areas in the world. According to USAFacts (2021), more than 53 million Americans, which is 17% of the U.S. population, are estimated to have insufficient access to affordable and healthy food, such as fresh fruits and vegetables. Perhaps interestingly, 96% of these people reside in urban areas (USAFacts, 2021). Food insecurity is directly linked to adverse health outcomes; hence, addressing this issue is of critical importance.

There are various support mechanisms that aim to directly improve vulnerable populations' access to food. For example, food bank is one support mechanism. See, for example, Sönmez et al. (2016), Hasnain et al. (2021), and Manshadi and Rodilitz (2022) for recent studies on food banks and volunteering operations. Apart from this, in the United States, Supplemental Nutrition Assistance Program (SNAP) is the largest federal program that supports low-income families for access to healthy food. See, for example, Levi et al. (2019) for an analysis of government interventions to promote nutritious food consumption. Food security is also related to a stream of operations management research that studies food waste. See, for example, Akkaş and Honhon (2022) and Belavina (2021).

5 | FUTURE DIRECTIONS I: TECHNOLOGICAL INNOVATIONS FOR A SUSTAINABLE AND INCLUSIVE WORLD

This section discusses key technological innovations for a sustainable and inclusive world, and presents future research directions for operations management scholars.

5.1 | Artificial intelligence (AI) and big data

AI is on its way to be an integral part of our society. Multi-agent intelligent supply chains predicted earlier are now a reality (Swaminathan et al., 1998). Organizations adopt AI in a wide variety of applications, ranging from self-driving cars to recruiting processes. Despite its benefits, the wide applicability of AI raises fairness concerns. AI systems are built on training data and algorithms designed by humans. The main concern is that if the training data or the design of the AI algorithm are biased toward any group, the output of AI can produce highly skewed results, hurting the inclusion and diversity in the society. Addressing this issue requires taking multiple steps. First, organizations should target for a diverse group of algorithm designers and data scientists. This would ensure that different backgrounds are considered in data collection and algorithm design phases. Second, organizations should avoid using actual or induced protected class (e.g., race, religion, national origin) in the training phase so that algorithms can perform in a bias-free way. Operations management community has taken important steps to study the fairness in AI (see, e.g., Baek & Farias, 2021; Kallus et al., 2022). However, we believe that more research is needed to study the diversity and inclusion aspects of AI. We note that this line of research complements the nascent operations management literature on racial inequalities, diversity, and women empowerment (Cachon & Kaaua, 2019; Cui et al., 2020a, 2021; Narayanan & Terris, 2020; Plambeck & Ramdas, 2020; Tang, 2022).

With the advent of technology, organizations now collect and store big data, and design data-driven policies to make better decisions. Big data offer ample opportunities to address pressing social issues. For example, organizations can harness big data to monitor or forecast climate change and identify vulnerable populations. Such advancements would help with the design of early warning systems and environmental policies. Corbett (2018) discusses how big data can be used to make better decisions in sustainability, and sheds light into some of the sustainability issues driven by the use of big data. Another application of big data is humanitarian operations. Swaminathan (2018) discusses the value of big data for different applications of humanitarian operations, and presents data sources that might help humanitarian organizations make data-driven decisions. Big data can also be used to design safe, smart, and inclusive cities; this goal is part of the U.N.'s SDGs.

5.2 | Blockchain

Blockchain technology—a distributed ledger technology that records transaction data in multiple places at the same time—has revolutionized the financial sector. See, for example, Babich and Hilary (2020) and Shibuya and Babich (2021) for the overview of the technology and an application in finance. Advantages of this technology include transparency, traceability, security, and decentralization. Businesses are currently expanding the applications of this technology, which are expected to be game-changing for supply chains. Walmart, De Beers, and Cargill are some of the major companies that invested in blockchain technology for their supply chain management (del Castillo, 2021). Transparency and traceability are the main value proposals of blockchain for supply chains. See, e.g., Cui et al. (2020b) that investigates the design of blockchain in supply chains, considering the technology's transparency benefit. However, firms need to carefully create strategies to be successful in the blockchain implementation (Lin et al., 2022).

A key application of blockchain technology is detecting counterfeits in supply chains, which is a pressing issue especially in pharmaceutical and luxury product supply chains. Pun et al. (2021) and Shen et al. (2022) examine the value of blockchain technology in combating counterfeits. Another important application of blockchain is responsible sourcing. See, for example, Sumkin et al. (2021) for an analysis of responsible sourcing with blockchain technology in diamond supply chains. We believe that there are opportunities to expand this stream to fully understand the impact of blockchain on sustainable practices.

Apart from these, blockchain might also have tremendous value in food supply chains. In the case of food contamination or outbreak of food-borne illnesses, it may take days or weeks to trace the entire food supply chain and determine the responsible party (HyperLedger Foundation, 2021). Blockchain technology decreases the tracing duration from days to a few seconds, helping organizations save lives. Reduced tracing duration also helps farmers because entire supply chain does not need to shut down for a prolonged time in the case of adverse events. Another important value proposition of the blockchain technology for food supply chains is to provide freshness transparency for perishable products, which might have drastic impact on the firms' inventory policies as well as food waste. Dong et al. (2020) and Keskin et al. (2021) analyze the value of blockchain technology for different applications in food supply chains.

5.3 | Internet-of-things (IoT)

IoT technology has many applications, ranging from smart energy to precision farming. Regarding the former, it is one of the key technologies that enable alert systems for responsible electricity consumption. Specifically, IoT energy platforms notify end users when there is an excessive electricity usage. By this way, the platforms help their members keep their consumption at a reasonable level. In collaboration with such an IoT platform, Duran et al. (2022) find that such notifications are considerably effective in reducing abnormal energy consumption as well as emissions. In addition to this application, applications of IoT in farming can be a fruitful area to study for operations management researchers.

5.4 | Telemedicine

Telemedicine is the practice of remotely providing clinical services to patients via information and telecommunication technologies, such as smartphones and computers. Relative to the prepandemic era, the usage of telemedicine has drastically increased during the pandemic. Other than eliminating the risk of COVID-19 infection during a medical visit, a key benefit of this technology is its convenience. Patients do not have to travel to medical facilities to benefit from telemedicine services; they can receive the care they need from their homes. This benefit is especially important for rural patients who do not have access to reliable transportation. Overall, telemedicine is essential to increase access to healthcare by delivering care to underserved populations who face barriers to in-person care. There are a few studies that analyze telemedicine as an innovative healthcare delivery model; see, for example, Bavafa et al. (2021) and Rajan et al. (2019). Most recently, Sunar and Staats (2022) analyze the impact of telemedicine on socioeconomic health disparities, and find that even in the absence of technology access disparities, introducing telemedicine can exacerbate health disparities between low- and high-income patients for certain population structures. We believe that, telemedicine will continue to be an integral part of the healthcare sector in the postpandemic era. Given the prominence of this technology, more research is needed to understand the pros and cons of it.

5.5 | Energy storage

This technology is essential to take full advantage of wind and solar energy, because it enables renewable energy storage and discharge at any point in time. Thus, it is the key technology that facilitates the renewable energy adoption. There are two types of energy storage systems: behind-the-meter (BTM) and front-of-the-meter (FOM). These systems differ in terms of where the consumption occurs relative to the electric meter. In BTM systems, generation and consumption occur without passing a meter. Hence, electricity end users can directly use the stored energy without interacting with the grid. Examples include residential solar plus storage systems and electric vehicles (EVs). In contrast, in FOM storage systems (e.g., utility-scale storage systems), electricity has to pass through a meter for end user consumption. Apart from this difference, BTM storage systems are typically smaller than FOM storage systems. Specifically, the size of a commercial or industrial BTM battery can be as large as 2 MW whereas the corresponding number for a residential BTM battery is typically 5 kW (IRENA, 2019). Storage systems, especially large-scale ones, are studied in various dimensions in the operations management literature; see, for example, Kaps et al. (2021), Kapuscinski et al. (2020), Wu et al. (2012), Qi et al. (2015), Zhou et al. (2016, 2019). Another stream of the literature focuses on the management of EVs, including pricing (Lin et al., 2022), charging strategies (Sun et al., 2019), infrastructure planning (Mak et al., 2013; Yu et al., 2022), subsidy design (Cohen et al., 2016), and adoption strategies (Abouee-Mehrizi et al., 2021; Avci et al., 2015; Sun et al., 2019). However, the small-scale solar plus storage systems are understudied in the literature. We believe that there are novel research opportunities in this direction.

6 | FUTURE DIRECTIONS II: BUSINESS MODEL/PROCESS INNOVATIONS FOR A SUSTAINABLE AND INCLUSIVE WORLD

Business model/process innovation requires costly investments. They might involve new product launch, and typically, there is uncertainty about the potential gain from such projects (Harrison & Sunar, 2015; Sunar et al., 2019). Firms that launch new products might face with limited supply during the initial period after launch (Kumar & Swaminathan, 2003). Furthermore, such firms might be exposed to imitation or competition (Sunar et al., 2021). Good news is that despite these and many other challenges, there are innovative business models and processes that aim to make the world a better place. This section discusses key business model/process innovations for a sustainable and inclusive world, and presents future research opportunities.

6.1 | Online platforms for social good

An innovative application of online platforms is in renewable energy. An online solar marketplace is an innovative business model that facilitates end users' solar panel adoption. It is essentially a shopping website that aims to help customers find an appropriate solar panel installer. This business model substantially decreases the search cost for potential adopters by providing customer reviews about installers, and connecting installers and potential customers online. In collaboration with the largest online solar marketplace in the Unites States, Huang et al. (2020b) find that the dispersion in customer reviews has an inverted-U shaped relationship with installer's activity levels and transactions in the marketplace, as well as the overall marketplace transactions. Thus, rating gating or review filtering, which is common in online marketplaces, might backfire for both marketplace operators and sellers.

Volunteer crowdsourcing is another innovative application of online platforms. These platforms notify a set of potential volunteers about a task to motivate them to volunteer for the completion of the task. See, for example, Manshadi and Rodilitz (2022) that designs policies for such platforms, including food bank volunteer platforms. Last, but not least, online platforms offer ample opportunities for small farmers in developing countries. See, for example, Levi et al. (2020) that studies the auction design for online agri-platforms in developing countries, and implements the proposed design in an Indian farmer market.

6.2 | Community solar: Increasing access to small-scale renewable energy

Although rooftop solar panel adoption is critical for decarbonizing the energy sector, many individuals do not have access to this technology. Lack of access can be because of various reasons. For example, many people live in rentals or multitenant buildings, and do not have the opportunity to adopt this technology. Even for single-tenant property owners, the roof space might not be suitable or sufficient to generate solar energy. Apart from these, it is costly to install solar panels. Thus, income could be another barrier to adoption. To address these challenges, a new business model—community solar—has emerged. Community solar projects are large-scale solar power plants whose benefits are shared by multiple properties. This is in contrast to the individual rooftop solar panel installations under which benefits are collected by single adopter. Specifically, Heeter et al. (2021) define the community solar as follows:

"...a solar installation with multiple offtakers or owners, referred to as "subscribers." The subscribers enter into a contractual relationship with the owner or operator of the installation (or an intermediary) to receive some or all of the financial returns from a predefined share of the installation's output."

A key advantage of this business model is that the cost of participating in these projects is much smaller compared with the investment cost of installing rooftop solar panels. With this feature, community solar significantly increases electricity end users' access to solar energy. This model may be successful in emerging countries and rural areas where cooperatives may already exist. As of now, the community solar capacity is doubling every year since 2010, and expected to grow substantially in the years to come (Heeter et al., 2021). In the United States, the installed community solar capacity is enough to provide electricity to 600,000 households; the United States targets to increase this number by more than 700% by 2025 (U.S. DOE, 2021).

There are challenges in expanding the community solar capacity. The main one is the regulation. Currently, 22 states and Washington, D.C., have policies that support community solar (NREL, 2021). Thus, as of now, community solar projects are limited to a specific geography in the United States. In fact, the majority of projects are located in four states: Massachusetts, New York, Minnesota, and Florida (Heeter et al., 2021). The virtual net metering policy, which allows the shared solar subscriber to receive electricity bill credits for their share of solar generation, is especially critical for the growth of this business model. Apart from this, the majority of community solar capacity is developed by third parties. Thus, the coordination of the utility, third-party developer, customers becomes a challenge in many projects. We believe that operations management researchers can contribute to the growth of this innovative business model by analyzing it from various directions.

6.3 | Power purchase agreements (PPAs) with renewable energy: Increasing access to large-scale renewable energy

As part of corporate social responsibility efforts, companies are increasingly pledging to meet their electricity demand from renewable energy sources. Globally, 315 organizations have joined the RE100 initiative, and targeted to meet 100% of their electricity demand from renewable energy by 2050 (RE100, 2021). To achieve this and related sustainability goals, many Fortune 500 companies, including Amazon, Alphabet, Facebook, and Microsoft, are signing long-term PPAs with independent renewable energy producers (Kobus et al., 2021). This innovative business model is critical for the growth of renewable energy producers as well as enabling small- or medium-sized firms access renewable energy because large-scale renewable energy investments are capital intensive. However, renewable PPAs are complicated contracts, and their implications should be well understood. Sunar and Birge (2021) study the optimal design of PPAs with renewable power producers, and the resulting capacity investments. More research is needed to understand the details of renewable PPAs.

6.4 | Energy poverty and social innovation for electricity access

Energy access is defined as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average" (IEA, 2020). While there is no universal definition for the electricity access, there are suggested electricity consumption thresholds for rural and urban populations that enable them to receive basic energy services, such as lighting and phone charging. Globally, 759 million people did not have access to electricity in 2019, and this is a major impediment to economic growth and poverty alleviation (The World Bank, 2021b). The majority of these underserved population is located in rural areas of sub-Saharan Africa (IEA et al., 2021). The main challenges in electrifying these areas are the expensive cost of grid expansion and the low income level in those regions.

The private sector devised innovative off-grid solutions to bring electricity to those who are in need. In this context, Uppari et al. (2019) analyze a business model with rechargeable bulbs. The authors characterize the pair of bulb capacity and recharge price that maximizes the firm's revenue. Guajardo (2019) empirically studies the interaction between consumer usage and payment behaviors in the solar lamp distribution for developing countries. We believe that there could be additional research opportunities in this direction.

6.5 | Corporate strategies to voluntarily reduce carbon footprints

Organizations have two key levers to voluntarily reduce their carbon footprints without changing their operations: carbon offsetting and buying renewable energy credits.

Voluntary carbon offsetting

Organizations can reduce their carbon footprints by purchasing the environmental benefit of a project that reduces or avoids emissions in any part of the world. These benefits are called carbon offsets, and traded in voluntary carbon offset markets. Many Fortune 500 Companies, including Delta, Alphabet, Salesforce, JP Morgan Chase, and Disney, are purchasing carbon offsets from voluntary markets to reduce their carbon footprints (Elgin, 2020; Statista, 2020). As a result of this growing interest, voluntary carbon markets have drastically been expanded in recent years. In 2021, transaction volume in these markets increased by 65% relative to 2020, with a value exceeding $1 billion for the first time

(Ecosystem Marketplace, 2021). Offset projects could be of various types, three of which are listed below:

- *Forestry and land use*: These projects aim to preserve and improve forest and soil. Some of them avoid emissions by preventing deforestation or degradation of existing forests. The others decrease emissions by forestation, or by implementing various techniques to sequester more carbon with existing forests/soil.
- *Renewable energy*: Examples include wind, solar photovoltaic, hydroelectric, and biomass power production projects.
- *Energy efficiency/fuel switching*: Energy-efficiency projects reduce emissions by using less fuel and energy than a business-as-usual scenario. Examples include upgrading a fleet of vehicles for fuel efficiency and renovating buildings to improve energy efficiency. Fuel switching projects reduces the amount of fossil fuel usage by replacing the existing fuel type with a cleaner or renewable one. An example is switching the fuel of an electricity generator from oil to natural gas.

Among these, renewable energy and forestry/land use offset projects are more common in practice. There is limited research on voluntary carbon offsetting in the operations management literature (see, e.g., Sunar & Plambeck, 2016; Gao and Souza, 2022). As future research, the operations management community can help managers and policy makers understand how using carbon offsets can affect firm profit and social welfare by analyzing different practical scenarios.

Renewable energy credits

Renewable energy credits, which are also called Renewable Energy Certificates (RECs), represent clean energy attributes of one megawatt hour renewable energy generation. This trading instrument gives the buyer the legal right to claim the environmental benefits associated with renewable energy generation. There are two types of RECs: bundled and unbundled. When RECs are sold with their associated energy, they are called bundled RECs. When RECs are sold separately from their associated energy, they are referred to as "unbundled RECs." Companies purchase both types to achieve voluntary renewable energy goals and/or offset their carbon emissions. However, the majority of the purchased RECs are unbundled. There are a few attractive features of unbundled RECs. First, buying unbundled RECs to achieve renewable energy goals does not require organizations to alter their existing electricity contracts. Second, unbundled RECs are typically originated from REC-oversupplied markets; thus, these credits tend to be very cheap compared to other means of voluntary renewable support instruments. Third, because they are not tied to the generated energy, these credits can be purchased from any location at any time, providing flexibility to corporations. We believe that there are opportunities for operations management researchers to contribute to the understanding of REC markets.

7 | CONCLUSION

In this paper, we review some of the recent advances in the operations management literature that aim to tackle challenging societal problems. Specifically, we focus on papers related to sustainable planet (renewable energy, environmentally and socially responsible operations, regulation-driven operations), inclusive health, and agriculture (with an emphasis on inclusion). We also identify future research opportunities for operations management scholars to further contribute to an inclusive and sustainable world. We classify future directions into two main topics: technological innovation (e.g., energy storage, smart meters, telemedicine, AI, IoT, and blockchain) and business model/process innovation (e.g., online platforms). We believe that there are tremendous opportunities for the operations management researchers to conduct research in these directions to advance the humanity in the right direction.

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