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TECHNICAL NOTE

Yinlun Huang[1]

Reinforcing Sustainability Assessment and Reshaping Technology Innovation for Highly Sustainable Manufacturing in the Post–COVID-19 Era

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1 Department of Chemical Engineering and Materials Science, Wayne State University, 5050 Anthony Wayne Dr., Detroit, MI 48202, USA (Corresponding author), e-mail: yhuang@wayne.edu, http://orcid.org/0000-0002-9118-4137

Reference

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ABSTRACT

The COVID-19 pandemic has caused an unprecedented shock around the world. Manufacturing sectors are among the hardest hit. As the initial negative effects of the COVID-19 pandemic start to recede, the manufacturing sectors must work collaboratively to develop strategies for transition to much more sustainable and resilient industries. These circumstances have created a number of research opportunities in sustainability science and engineering. This technical note discusses challenges and research needs in the effort to introduce new aspects to enhance existing sustainability metrics systems and to develop powerful decision analysis and decision-making methodologies and tools for reshaping technology innovations.

Keywords

sustainability assessment, technology innovation, manufacturing sustainability, post–COVID-19

Introduction

The COVID-19 pandemic has ushered in various unprecedented challenges and severely disrupted economic and social systems worldwide. In the United States, one of the sectors that has been hit hardest by the pandemic is the manufacturing industry. Health risks, demand reduction, supply chain disruption, etc., have slowed numerous manufacturing facilities to a standstill. It is impossible to predict when the coronavirus will die down. According to Lloyd,[1] automotive production, for example, will be unlikely to recover until after 2024. This has seriously affected many original equipment manufacturers, suppliers and distributors, chemical and material manufactures, fuel producers, and many more.[2]

Industries are looking beyond the fog of uncertainty toward long-term changes and developing strategies for more sustainable and resilient development in the future.

Rethinking Sustainability and System Transition

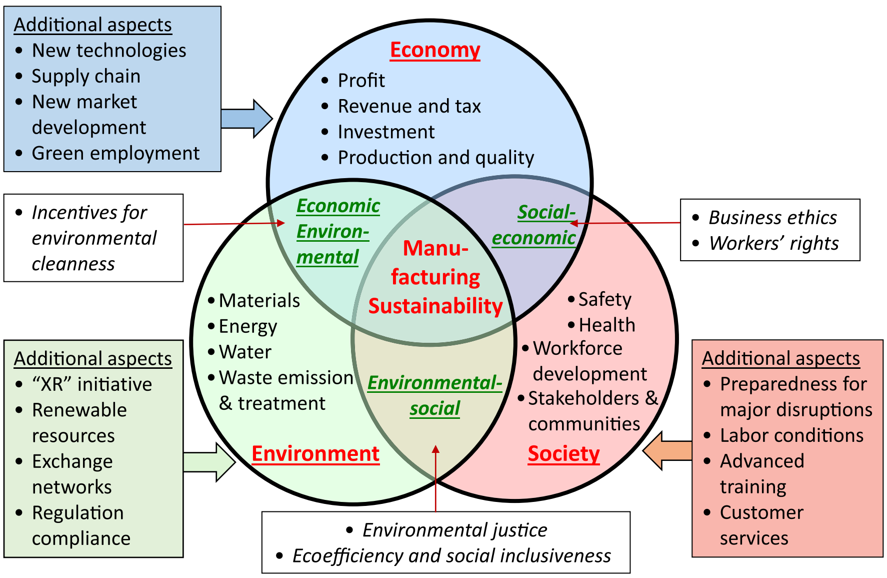
Sustainable manufacturing is the creation of products through economically sound processes that minimize negative environmental impacts while conserving energy and natural resources. It also enhances employee, community, and product safety.[3] Companies implementing effectively sustainable development strategies have demonstrated competitive advantages. In practice, they set a short-to-long-term sustainability goal, then identify a sustainability metrics system, perform a sustainability assessment, conduct sustainability analysis, derive optimal strategies, take actions, and evaluate sustainability performance improvement effectiveness. This process is often repeated to ensure goal achievement.

The outbreak of COVID-19 has raised deliberation in the sustainable engineering community to rethink the very concept of sustainability. Hakovirta and Denuwara[4] suggested introducing "human health" as the fourth pillar of sustainability. Note that human health has been already included in various sustainability metrics systems, e.g., the metrics introduced by the Institution of Chemical Engineers (IChemE).[5] But health-related sustainability indicators are normally limited to employees' health and safety in workplace. Bodenheimer and Leidenberger[6] discussed opportunities for promoting sustainability transitions in consumption and production that could be achieved with deliberate planning and strategic communication in the public sphere. Sustainability transition is an important area in sustainability science and engineering.[7] Recently, Moradi-Aliabadi and Huang introduced a vector-based sustainability analysis and decision-making method to facilitate the study of short-to-long-term sustainability transition.[8,9] However, the known methodologies are all based on conventional sustainability assessment and existing technologies.

Enhancement of Sustainability Metrics Systems

Sustainability metrics systems usually cover various aspects that are important to industries. **Figure 1** presents an example in which four major aspects within each of the three circles are listed. Each aspect is evaluated by multiple

FIG. 1 Triple-bottom-line–based sustainability and addition of new aspects.



sustainability indicators. The IChemE Sustainability Metrics, for instance, contain 49 indicators.[5] To make the sustainability assessment more comprehensive, especially for industries that may experience major disruptions caused by global, national, or subnational disasters, additional aspects and thus indicators should be explicitly included.

ECONOMIC ASPECTS

Over the past decade, numerous technologies have been developed to advance manufacturing. The net benefits that could be offered to industries should be comprehensively evaluated in the sustainability domain. The robustness and resiliency of the supply chain, either global or local, and the effectiveness of developing new markets should be also assessed; these factors are critical for helping industries survive disruptions. According to Bowen, Kuralbayeva, and Tipoe,[10] 19.4 % of U.S. workers could currently be considered part of the green economy in a broad sense. Green job transition should be considered as a new strategy, as it should potentially contribute significantly to economic growth. The four additional aspects to the economic sustainability category shown in **figure 1** are new to the conventional metrics systems.

ENVIRONMENTAL ASPECTS

The 3Rs (reduce, reuse, and recycle) Initiative was first introduced by Japan at the 2004 G8 Summit in Georgia. The United States and Japan reaffirmed the goals of the Initiative in 2007. In recent years, the 3Rs have been expanded to 6Rs (i.e., adding recover, redesign, and remanufacturing)[11] and beyond (e.g., reclamation, repurposing, and reintegration), depending on the type of manufacturing. It is highly recommended that companies launch XR ($X > 3$) initiatives if they have not done so already. The effectiveness of such initiatives should be evaluated annually. Renewable resource utilization is becoming increasingly feasible. The establishment of exchange networks with other companies is another important pathway for participating companies to minimize waste materials and energy. In addition, the effectiveness of regulation compliance should be examined. These additional aspects to the environmental sustainability category are shown in **figure 1**.

SOCIAL ASPECTS

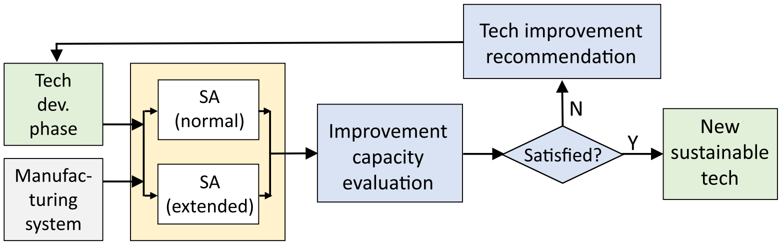
The lessons learned from the COVID-19 pandemic will undoubtedly help manufacturers to think deeply if the world faces a second wave of the virus or another major disastrous event in the future. Therefore, it is imperative for them to develop strategies and guidelines to prepare for possible major disruptions. Labor conditions, especially more comprehensive health risks to employees, customers, and local communities, should be counted seriously. Advanced training of workforces, especially training for new technologies and guidelines as well as improved communications and services to customers, should all be emphasized (see the additional aspects to the social sustainability category in **fig. 1**).

RESEARCH OPPORTUNITY

The inclusion of the 12 new aspects described and thus the addition of a number of new sustainability indicators in different categories should enhance sustainability assessment significantly for manufacturing sectors in the post–COVID-19 era. The new indicators need to be carefully designed to provide precise coverage of the new aspects and minimize redundancy with existing indicators. Note that a sustainability metrics system with too many indicators could be a challenge to users/decision makers in indicator selection and assessment. This demands the development of at least the following methodologies for (1) consolidating indicators in each category and subcategory, (2) constructing composite indicators for evaluating economic-environmental, environmental-social, and social-economic performance, (3) aggregating indicators in groups and as a whole, especially when both hard and soft (qualitative) indicators are in the same group, and (4) predictive assessment under severe scenarios, especially with uncertain information.

FIG. 2

General procedure for reshaping technology innovation for sustainable manufacturing. Dev. = development; tech = technology.



Reshaping Technology Innovation

Technology innovation is a key approach to continuously improving manufacturing sustainability. It is certain that more new technologies will be developed to help manufacturing sectors predict the impact of unprecedented events and respond more quickly and effectively. In recent decades, technology assessment (TA) has been actively studied. It is considered a designation of approaches for investigating the conditions and consequences of technologies.[12] However, it is shown that there has been no systematic method for TA in the triple-bottom-line–based sustainability space, especially for balanced sustainable development. This may render uncertain the whole spectrum of sustainability performance of some new technologies.

RESEARCH OPPORTUNITY

This may be a crucial opportunity for researchers to study how to develop novel methodologies and powerful tools that can help reshape technology innovation to meet sustainability goals. Such methods and tools should be effective in conducting systematic sustainability assessment of new technologies in their early development phase using enhanced sustainability metrics systems, such as those discussed in the preceding section. They should be capable of identifying the capacities of new technologies in sustainability performance improvement after being adopted in manufacturing systems. The capacity evaluation should be not only for normal manufacturing but also for the manufacturing taking place during a major disruption for an uncertain period of time, as during the COVID-19 pandemic. Therefore, it is most likely that multiple technologies of different functions will be identified for simultaneous adoption by manufacturers to achieve their sustainability goals. Admittedly, this is a very challenging task, as it involves not only short-to-long-term goals but also a need to handle unpredictable disruptive situations.

The anticipated new TA and decision-making tools should be capable of deriving optimal recommendations under conditions involving multiple objectives, short-to-long-term goals, unpredictable crises, and severe data uncertainty. Such tools should be intelligent enough to interact with decision makers, gain deep understanding of scenarios, and perform comprehensive analysis of possibly a large amount of data. **Figure 2** presents a general procedure for reshaping technology innovation, where SA (normal) indicates sustainability assessment under normal manufacturing conditions, while SA (extended) is the assessment using newly introduced sustainability indicators that reflect the additional aspects listed in **figure 1**. The new technologies developed by implementing this procedure should be not only sustainable but also capable of improving manufacturing systems' capabilities when facing unexpected major disruptions. Note that the functional block in **figure 2**, "Technology Improvement Recommendation," is scientifically very challenging in development.

Concluding Remarks

As the initial negative effects of the COVID-19 pandemic start to recede in the near future, the manufacturing sectors will begin adjusting to the new normal, with a goal to ensure robust sustainability and resilience. To help achieve this goal, we believe that the sustainability metrics systems designed originally for conventional manufacturing should be expanded to include a number of new indicators based on the newly introduced 12 aspects. There is also a prime opportunity for technology inventors to reshape technology innovations by addressing additional sustainability challenges in the early development phase. Facing new challenges, researchers should take them as the opportunity to introduce new theories, methodologies, and tools for industries to transition to highly sustainable manufacturing.

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References

1. A. Lloyd, "Impact of COVID-19 on the Manufacturing Industry," Interact Analysis, http://web.archive.org/web/20201008161224/https://www.interactanalysis.com/impact-of-covid-19-on-the-manufacturing-industry-infographic/
2. A. W. Bartik, M. Bertrand, Z. Cullen, E. L. Glaeser, M. Luca, and C. Stanton, "The Impact of COVID-19 on Small Business Outcomes and Expectations," *Proceedings of the National Academy of Science of the United States of America* 117, no. 30 (July 2020): 17656–17666, https://doi.org/10.1073/pnas.2006991117
3. "Sustainable Manufacturing," United States Environmental Protection Agency, http://web.archive.org/web/20201008161745/https://www.epa.gov/sustainability/sustainable-manufacturing
4. M. Hakovirta and N. Denuwara, "How COVID-19 Redefines the Concept of Sustainability," *Sustainability* 12, no. 9 (May 2020): 3727, https://doi.org/10.3390/su12093727
5. Institution of Chemical Engineers, "The Sustainability Metrics: Sustainable Development Progress Metrics Recommended for Use in the Process Industries," Institution of Chemical Engineers 2002, http://web.archive.org/web/20201001133227/https://www.greenbiz.com/sites/default/files/document/O16F26202.pdf
6. M. Bodenheimer and J. Leidenberger, "COVID-19 as a Window of Opportunity for Sustainability Transitions? Narratives and Communication Strategies Beyond the Pandemic," *Sustainability: Science, Practice and Policy* 16, no. 1 (2020): 61–66.
7. T. M. Parris and R. W. Kates, "Characterizing a Sustainability Transition: Goals, Targets, Trends, and Driving Forces," *Proceedings of the National Academy of Sciences of the United States of America* 100, no. 14 (July 2003): 8068–8073, https://doi.org/10.1073/pnas.1231336100
8. M. Moradi-Aliabadi and Y. Huang, "Vector-Based Sustainability Analytics: A Methodological Study on System Transition Toward Sustainability," *Industrial and Engineering Chemistry Research* 55, no. 12 (March 2016): 3239–3252, https://doi.org/10.1021/acs.iecr.5b03391
9. M. Moradi-Aliabadi and Y. Huang, "Decision Support for Enhancement of Manufacturing Sustainability: A Hierarchical Control Approach," *ACS Sustainable Chemistry and Engineering* 6, no. 4 (April 2018): 4809–4820, https://doi.org/10.1021/acssuschemeng.7b04090
10. A. Bowen, K. Kuralbayeva, and E. L. Tipoe, "Characterising Green Employment: The Impacts of 'Greening' on Workforce Composition," *Energy Economics* 72 (May 2018): 263–275, https://doi.org/10.1016/j.eneco.2018.03.015
11. I. S. Jawahir and R. Bradley, "Technological Elements of Circular Economy and the Principles of 6R-Based Closed-Loop Material Flow in Sustainable Manufacturing," *Procedia CIRP* 40 (2016): 103–108, https://doi.org/10.1016/j.procir.2016.01.067
12. A. T. Kearney, *Technology and Innovation for the Future of Production: Accelerating Value Creation* (Geneva, Switzerland: World Economic Forum, 2017), http://web.archive.org/web/20201008164108/http://www3.weforum.org/docs/WEF_White_Paper_Technology_Innovation_Future_of_Production_2017.pdf