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Proceeding Paper

The Impacts of the Pandemic on Sustainable Production and Consumption: Toward a System Dynamics Approach †

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Abstract: The pandemic in 2020 called for developing a recovery plan and action in designing a robust and sustainable supply chain worldwide. In developing the models in the context of sustainable development, a holistic approach is needed. Hence, the stakeholders' value chain, the impacts of policies, and short/medium- and long-term planning horizon should be integrated into developing and analyzing the models. This work in progress research proposes a system dynamic approach for addressing the impacts of the pandemic on goal 12. First, the subsystems and causal loop diagram of the main elements of sustainable production and consumption are provided. Then, the scenarios and the perspective of application are discussed.

Keywords: pandemic; sustainable goals; production and consumption; system dynamics

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1. Introduction

Sustainable development goals are the common agenda for nations to save our planet. The UN SDG outline includes 17 goals with several targets for the operationalization of sustainable development by 2030. The COVID-19 pandemic influenced the global economy, business, socio-economic systems, and human behaviors with different short- and long-term impacts on the people, planet, and profit. One of the essential goals in the UN agenda is goal 12 that seeks sustainable production and consumption. This goal includes different stakeholders and covers the life cycle approach of several sectors including mobility, food, agriculture, housing, and appliances. By June 2021, the pandemic, with more than 177 million cases and 3.8 million deaths, influenced the realization of SDG goals. The main elements in goal 12, including reducing material consumption and footprint, increasing the recycling rate, decreasing food waste, management of hazardous substances, and increasing the number of policies for promoting sustainable production and consumption. The impacts of the pandemic on these targets should be analyzed by considering certain scenarios. Several studies recently focused on the impacts of COVID-19 on supply chain and logistics [1–4]. A few studies also studied the impacts on some of the SDG goals. However, to the best of our knowledge, addressing the impacts of the pandemic on goal 12 in a systematic way and via a simulation model was not a prime focus of prior research. The system dynamics approach provides the opportunity to assess a large-scale problem with several influential factors [5]. This study aims to discuss the application of system dynamics in evaluating the impacts of COVID-19 on goal 12. The rest of the paper is organized as follows: Section 2 discusses the literature review. Sections 3 and 4 provides the methodology, the model, the scenarios, and the application perspective. Finally, Section 5 provides a summary and future research.

2. Literature Review

In this section, a brief review on goal 12, the research on sustainable production and consumption, the studies on the impacts of COVID-19 on SDG goals, and the system dynamics approach are provided.

2.1. Goal 12 and the Current Situation

In 2015, the 2030 agenda for sustainable development is agreed upon by all the United Nations members. This agenda with 17 goals provides the shared values for protecting our planet and aids in peace and wealth for all people [6]. One of these goals is ensuring sustainable production and consumption pattern (goal 12) with 11 targets. The indicators based on the UNEP source are provided in Figure 1 [7]. These indicators aid in measuring the achievement of the determined targets to help nations' performance evaluation in the sustainability of production and consumption and highlight the deviations for taking appropriate actions. These indicators include the policies for sustainable procurement, the material footprint, the food wastes, the recycling rate, the hazardous substances, publishing corporate social responsibility reports by companies, and material consumption. The pandemic in 2020 influenced the achievement of these targets. According to the UN report, in 2010, the global material footprint was 73.2 billion metric tonnes that are increased by 17.3% in 2017. From 2017 to 2019, for 79 counties and the EU, at least one policy related to goal 12 is reported. By 2019, only 20% of electronic wastes are recycled, and these wastes are grown by 38%. Despite the target of reducing the fuel subsidies, they were increased by 34% from 2015 to 2018. The food wastes through the supply chain stream were reported at around 13.8% in 2016 [8].

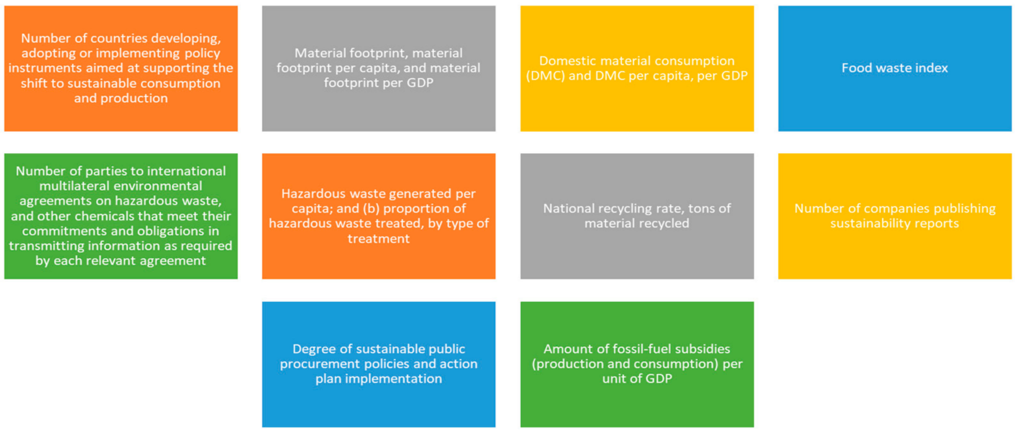

Figure 1. The indicators for goal 12 (source of data: UNEP [7]).

2.2. SDG Goals and Impacts of the Pandemic

Pradhan et al., performed a systematic review on the interactions between SDG goals. They considered the positive correlation as synergy and the negative as a trade-off. On the basis of the indicators and the data of 227 countries, they concluded that goal 1 (no poverty) has the most synergetic relations with the other SDG goals, and goal 12 is most linked to the trade-offs. Hence, for trade-offs, indicators and targets should be well discussed and negotiated for achieving better outcomes of these strategies [9]. Sala and Castellani used a life cycle assessment approach for evaluating the environmental impacts of food, mobility, housing, household goods, and appliances. They concluded that food is the most important area of consideration. The use phase plays an essential role in mobility, appliances, and consumption housing. For food and household goods, the upstream of the supply chain plays an essential role in environmental impacts [10]. Gasper et al., discussed goal 12, related targets, indicators, and policies. They mentioned that several challenges are existed related to the indicators and monitoring the target across the countries. They suggested developing the national targets for improving the outcomes [11]. Chan et al., reviewed goal 12 and they highlighted several gaps including focusing on the material footprint with reducing the overall consumption, improving the knowledge of decision-makers, policymakers, consumers, and businesses on sustainable production and consumption [12].

A few studies recently considered the impacts of the pandemic on goal 12. Elavarasan et al., studied the impacts of the pandemic on goal 7 (energy sustainability). They used

AHP and SWOT analysis to address the post-pandemic scenarios. They also discussed the impacts of COVID-19 on all 17 SDG goals and the challenges and solutions of the energy sector. For goal 12, they mentioned the availability of resources in healthcare systems and hospitals and the generated medical wastes during the pandemic as an important challenge. They suggested the optimization of consumption and production, promoting the 3R approach (reducing, reusing, recycling) and using the sharing platforms as the solutions for dealing with challenges [13]. Nundy et al., studied the impacts of the pandemic on energy, transport, and socio-economic sectors. They mentioned decreasing the energy demand in the transport sector and revenue loss while increasing energy consumption in the residential sector. The pandemic influenced SDG targets achievement by 2030, and a collaborative mitigation plan is required [14]. Health also considered the impacts of the pandemic on SDG goals. The author discussed that achieving goals 7–9 and 11–15 with the long-term impacts of COVID-19 is challenging. The economic recession affects the policies and the implementation of SDG goals [15]. Several studies addressed the impacts of the pandemic on supply chain and logistics [1–4]. Kumar et al., discussed the impacts of the pandemic on sustainable production and consumption. They recommended the policies in this area. For production, the policies should be revised to consider the impacts of COVID-19 with appropriate incentives. Industry 4.0 and digital manufacturing should be developed. The coordination between different stakeholders should be performed. The real-time monitoring and control of production could reduce the impacts of disruption. For consumption, e-commerce is growing considerably during the lockdowns. The role of social media is essential in evaluating consumers' behavior. The uncertainties of the consumers' demand should be managed with the resilience of the supply chain and certain strategies for risk management [16].

2.3. System Dynamics Approach in the Sustainable Development Context

System dynamics is a powerful approach for assessing the complexity and the interaction of the dynamics models. This approach is used in the context of sustainable development considering the complexity, the role of different stakeholders, and the variation in the influential variables. Hjorth et al., used system dynamics in the context of sustainable development. They mentioned complexity and the self-organizing system as the characteristics for using this approach [17]. Giannis et al., used system dynamics for evaluating different recycling scenarios. They applied this approach due to several influential factors on waste management including population, rapid economic growth, and consumer patterns [5].

The synthesis of the literature highlight the following points:

- Goal 12 of SDG plays an essential role in sustainability and more research is required considering the trade-offs, the complexity, and the challenges of the current indicators.
- The pandemic affects the realization of SDG goals by 2030. A few studies discussed the impacts on the goals. However, focusing on goal 12 and the related indicators has not received much attention in the literature.
- System dynamics is an effective approach for addressing the complexity and self-organizing nature of sustainable development problems. This approach could aid in analyzing the impacts of COVID-19 on the key elements of goal 12.

3. Research Approach

In this section, first, the essential indicators of goal 12 related to production and consumption are addressed. For this study, we focused on domestic material consumption, material footprint, food wastes, and recycling rate. The software Vensim PLE was used for designing a system dynamic model. Figure 2 shows the causal loop diagram. The increasing number of COVID-19 patients caused several shutdowns of manufacturing units and led to supply chain disruption, reduction in logistics operation, and transport. The resulted disruption decreased the allocated resources of the enterprises on sustainable procurement and publishing the corporate social responsibilities (CSR) reports. The priorities for the countries are shifted as the results of the loads on healthcare systems and hospitals. Hence, it decreases the number of developed and adopted policies in sustainable production and consumption. The disruption in the logistics and supply chain also caused a decrease in the material footprint and hazardous wastes generated from factories. The lockdowns of restaurants and the cities contributed to decreasing food wastes. However, the impacts on the wastes through the supply chain require detailed data. The huge consumption of medical protection items such as glasses, face shields, surgical masks, and gloves generated a considerable amount of solid waste. The recycling, landfilling, and proper treatment of these wastes should be addressed in the related policies. The main dynamic equations in this study are presented in this section. Equations (1)–(5) show the system equations based on UNEP metadata of the goal's 12 indicators [7]. Three elements are essential in domestic material consumption: direct import material, domestic extraction, and direct exports. For material footprint, the raw material of import, domestic extraction, and raw material of exports should be considered. Food wastes are the result of two indexes: food waste proportion to total wastes and the food wastes during different supply chain tiers. The other indicator is recycling rate, which is a function of material recycled, material exported and imported for recycling, and total wastes. Figure 3 shows the system dynamic model including five subsystems.

$$\mathrm{DMC} = M_{Im} + M_{Ext} - M_{exp} \tag{1}$$

$$MF = RM_{Im} + M_{Ext} - RM_{ex} \tag{2}$$

$$Food_{wastes} = \left\{ \frac{Fw}{T\_W}, \sum_{i=1}^{n} Fw_{tier_i} \right\} \tag{3}$$

$$R_{rate} = \frac{(M_{recy} + M_{exp\text{-}recy} - M_{Imp\text{-}recy})}{T\_W} \times 100 \tag{4}$$

$$T_W = W_{man} + W_{Econ} + W_{e,g,s,a\text{-}supply} + W_{mun} \tag{5}$$

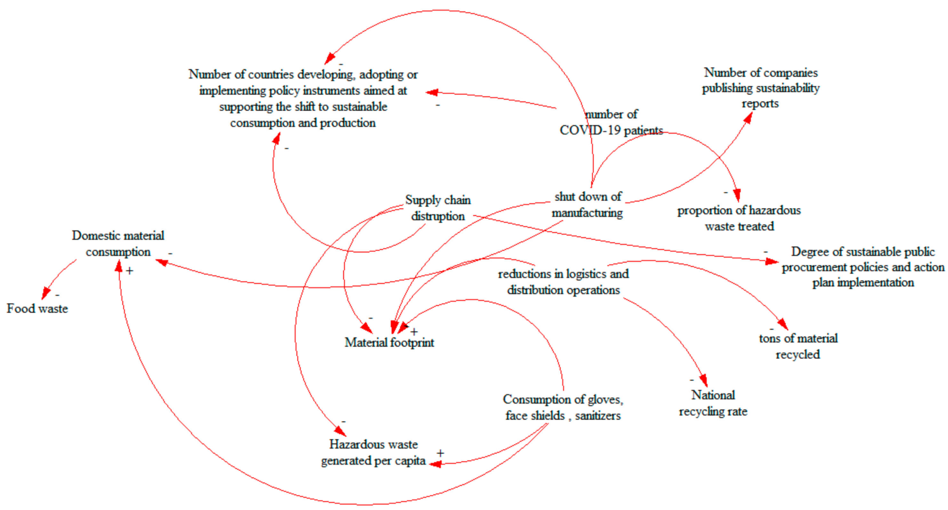

Figure 2. Causal loop diagram model for the impacts of the pandemic on goal 12 indicators.

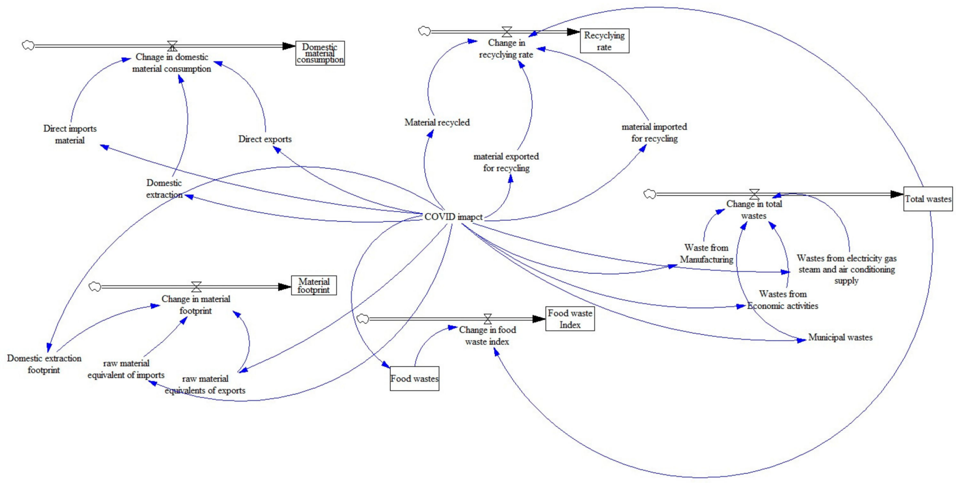

Figure 3. The system dynamic model with five sub-systems.

The first sub-system is domestic material consumption. The second is the material footprint. The national recycling rate, total wastes, and the food wastes index are the third, fourth, and fifth sub-systems in the proposed model, respectively. A scenario generation process based on the COVID-19 data could be designed to address the different states. For example, Ivanov used three scenarios for addressing the impacts of COVID-19 on the supply chain disruption (S1: outbreak in China, S2: outbreak in China, US and Europe, and S3: epidemic crisis) [1]. The severity and the duration could be added for building different scenarios. Table 1 shows the examples of the scenarios based on three factors of the region: outbreak, severity, and duration.

Table 1. The examples of the generated scenarios.

Scenarios	Regions' Outbreak	Severity	Duration
1	Asia	High	3 months
2	Asia + US and Europe	High	6 months
3	Asia	Moderate	3 months
4	Asia + US and Europe	Moderate	3 months

4. Application Perspective

One of the main challenges in performance evaluation based on SDG goals is the availability of data. Tracking and tracing these data is challenging due to the complexity of the supply chain and the interaction among the sectors. For example, measuring the wastes in different food supply chain tiers is challenging. Hence, for facilitating accessing data, the country data are proposed for testing and validating the model. The uncertainties in data are related to the randomness of a factor and the lack of knowledge [8,18]. In this context, using the fuzzy number is promising for the design of the experiment. Hence, using the data of Canada and applying fuzzy numbers for some of the variables is the authors' agenda for the completion of this work in progress research.

5. Conclusions

The operationalization of sustainable development in supply chain and logistics is the key issue in the realization of the United Nations (UN) goals. Goal 12 addresses responsible production and consumption. It includes the sustainable use of natural resources, waste management, applying sustainability through 3R (Reduce, Reuse, and Recycle), and management of the product's life cycle. According to the recent report of the UN, we still face challenges in achieving sustainable production and consumption. The consumption of natural resources is not sustainable. The recycling rate of the consumed products, particularly the electronic products, is far from the target rate. The wastes in the food supply chain during harvesting, transportation, processing, and storage are considerable. Reduction in oil prices and fossil fuel subsidies lead to more emissions and climate change. Technology revolution could play an essential role as leverage in achieving sustainable development goals. The UN's sustainable development goals are interconnected. Moreover, sustainable production and consumption and industry 4.0 play an essential role in future city planning. Smart sustainable cities are an emerging research theme that addresses the main concerns in planning, transportation, energy consumption, and the risks related to climate change in the new digitalization era. The pandemic in 2020 changed the global production and consumption patterns and affected the strategies and policies in achieving the SDG goals. The system dynamics approach provides a simulation environment for analyzing the different scenarios. The multiple feedback relationship between material consumption, material footprint, recycling rate, total wastes, and the food wastes index sub-systems are designed to permit analyzing different scenarios and the impacts on goal 12. This visualization tool aids decision-makers and policy planners in developing effective strategies and new indicators in the context of SDG. In this study, we focused on five essential subsystems on the basis of the goal 12 indicators. However, considering the subsystem related to the number of countries adopting and implementing policies related to sustainable production and consumption, hazardous waste management, publishing CSR reports, and fossil fuel subsidies are also proposed as future research.

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Abbreviations

DMC	Domestic material consumption
M_{Im}	Direct imports material
M_{Ext}	Domestic extraction
M_{exp}	Direct exports
MF	Material footprint
RM_{Im}	Raw material equivalent of imports
RM_{ex}	Raw material equivalents of exports
$Food_{wastes}$	Food wastes in the waste stream and in the supply chain
Fw	Food wastes
T_W	Total wastes
Fw_{tier_i}	Food wastes generated in tier i of the supply chain
R_{rate}	Recycling rate
M_{recy}	Material recycled
$M_{exp\text{-}recy}$	Material exported for recycling
$M_{Imp\text{-}recy}$	Material imported for recycling
W_{man}	Waste from Manufacturing
W_{Econ}	Waste from other economic activities
$W_{e,g,s,a\text{-}supply}$	Waste from electricity, gas, steam, and air conditioning supply
W_{mun}	Municipal Wastes

References

1. Ivanov, D. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *136*, 101922. [CrossRef] [PubMed]
2. Govindan, K.; Mina, H.; Alavi, B. A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19). *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *138*, 101967. [CrossRef] [PubMed]
3. Shokrani, A.; Loukaides, E.G.; Elias, E.; Lunt, A.J. Exploration of alternative supply chains and distributed manufacturing in response to COVID-19; a case study of medical face shields. *Mater. Des.* **2020**, *192*, 108749. [CrossRef] [PubMed]
4. Sarkis, J.; Cohen, M.J.; Dewick, P.; Schröder, P. A brave new world: Lessons from the COVID-19 pandemic for transitioning to sustainable supply and production. *Resour. Conserv. Recycl.* **2020**, *159*, 104894. [CrossRef] [PubMed]

5. Giannis, A.; Chen, M.; Yin, K.; Tong, H.; Veksha, A. Application of system dynamics modeling for evaluation of different recycling scenarios in Singapore. *J. Mater. Cycles Waste Manag.* **2016**, *19*, 1177–1185. [CrossRef]
6. The Sustainable Development Goals, United Nations. Sustainable Development Goals. 2018. Available online: https://www.un.org/development/desa/publications/the-sustainable-development-goals-report-2018.html (accessed on 5 April 2022).
7. UNEP. Available online: https://www.unep.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-12 (accessed on 5 April 2022).
8. Keivanpour, S. An Integrated Approach to Value Chain Analysis of End of Life Aircraft Treatment. Ph.D. Thesis, Université Laval, Québec, QC, Canada, 2015.
9. Pradhan, P.; Costa, L.; Rybski, D.; Lucht, W.; Kropp, J.P. A systematic study of sustainable development goal (SDG) interactions. *Earths Future* **2017**, *5*, 1169–1179. [CrossRef]
10. Sala, S.; Castellani, V. The consumer footprint: Monitoring sustainable development goal 12 with process-based life cycle assessment. *J. Clean. Prod.* **2019**, *240*, 118050. [CrossRef] [PubMed]
11. Gasper, D.; Shah, A.; Tankha, S. The framing of sustainable consumption and production in SDG 12. *Glob. Policy* **2019**, *10*, 83–95. [CrossRef]
12. Chan, S.; Weitz, N.; Persson, Å.; Trimmer, C. *SDG 12: Responsible Consumption and Production*; A Review of Research Needs. Technical Annex to the Formas Report Forskning för Agenda 2030; Stockholm Environment Institute: Stockholm, Sweden, 2018.
13. Elavarasan, R.M.; Pugazhendhi, R.; Jamal, T.; Dyduch, J.; Arif, M.; Kumar, N.M.; Shafiullah, G.; Chopra, S.S.; Nadarajah, M. Envisioning the UN Sustainable Development Goals (SDGs) through the lens of energy sustainability (SDG 7) in the post-COVID-19 world. *Appl. Energy* **2021**, *292*, 116665. [CrossRef]
14. Nundy, S.; Ghosh, A.; Mesloub, A.; Albaqawy, G.A.; Alnaim, M.M. Impact of COVID-19 pandemic on socio-economic, energy-environment and transport sector globally and sustainable development goal (SDG). *J. Clean. Prod.* **2021**, *312*, 127705. [CrossRef]
15. The Lancet Public Health. Will the COVID-19 pandemic threaten the SDGs? *Lancet Public Health* **2020**, *5*, e460. [CrossRef]
16. Kumar, A.; Luthra, S.; Mangla, S.K.; Kazançoğlu, Y. COVID-19 impact on sustainable production and operations management. *Sustain. Oper. Comput.* **2020**, *1*, 1–7. [CrossRef]
17. Hjorth, P.; Bagheri, A. Navigating towards sustainable development: A system dynamics approach. *Futures* **2006**, *38*, 74–92. [CrossRef]
18. Pishvaee, M.S.; Torabi, S.A. A possibilistic programming approach for closed-loop supply chain network design under uncertainty. *Fuzzy Sets Syst.* **2010**, *161*, 2668–2683. [CrossRef]