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Sustainable Digitalization by Leveraging Digitainability Matrix in Supply Chain

Manish Shashi

Abstract*: Digitalization, also called digital transformation, applies digital technologies and enablers to bring transparency and intelligence to operations to increase efficiency. Sustainability aims to responsibly control the impact of operations on society and the environment. Digitalization creates new opportunities and possibilities for business but also produces new challenges in sustainability. In most cases, strategies related to digitalization and sustainability operate independently and are driven by separate sub-organizations in a decentralized and sporadic manner. A digital maturity model is a valuable tool to access the current state of the supply chain and guide it toward a better state of digitalization. The digitainability matrix, also knowns as the digital sustainability matrix, serves as a collaborative method to address any potential short-term or long-term undesired effects of digital technology usage. A seamless global supply chain with sustainability at the center of all activities and adopting visibility and integration at all touch points helps organizations. Business managers should adopt green digitalization tools to improve their sustainability performance which is vital to improve an organization's triple bottom line: profit, people, and the planet.

Keywords: Digitalization, Digitainability, Supply Chain, Sustainability.

I. INTRODUCTION

Digitalization is the transformation of business models due to fundamental changes to core internal processes, customer interfaces, products, and services, as well as information and communications technologies [5]. Another way to define digitalization in supply chain management is the changes in value creation by the use of digital transformation technologies (DTT), the adaptation of strategies and processes, and the adaptation of enablers such as innovation and leadership to support the achievement of goals such as an increase in agility, higher productivity and a more customer-centric supply chain [11].

Sustainability, as defined by the United Nations World Commission on Environment and Development, is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs [5]." Triple bottom line (TBL) sustainability theory suggests that supply chain managers must consider social, economic, and ecological objectives while deciding to make their business profitable [18]. The TBL sustainability approach comprises smartness and sustainability dimensions that introduce smartness, covering availability, integrity, and adaptability sub-dimension [17].

The technologies used in digitalization may impact sustainability in many ways, such as pollution and depletion of natural resources. The harmful and excessive quantity of greenhouse gases (GHG) such as carbon dioxide (CO2), carbon monoxide (CO), methane (CH4), nitrous oxide (N2O), and fluorinated gases may enter the earth's environment as a result of transportation, burning fossil fuels for electricity, heat and factories outputs. The warehouse is responsible for almost 13% of supply chain GHG emissions. Davis et al. (2011) discovered a consistent set of carbon inventories that spans the entire supply chain of global CO2 emissions, finding that 10.2 billion tons of CO2, or 37% of global emissions, are from fossil fuels traded internationally and an additional 6.4 billion tons CO2 or 23% of global emissions are embodied in traded goods [20]. In 2020, CO2 accounted for about 79% of all US greenhouse gas emissions from human activities. Oshita (2012) explained that supply chain path identification is critical in driving changes in the lifecycle of CO2 emissions [21]. It helps supply chain managers with information on the critical paths for efficiently reducing CO2 emissions [21].

The internet is a global marketplace that provides many opportunities for collaboration, innovation, and communication in the digitalization journey. The internet emits 3.7% CO2 emission per year, which equals the amount produced by the airline industry. One megabyte of email emits 20g of CO2, equivalent to 25 minutes lit of an old 60 W bulb. 20 emails a day per user for a year creates the carbon dioxide emission equal to a car traveling for 1000 kilometers.

Digital transformation is about changing the existing culture and how we work to serve our end customers by fostering digital culture. It may take all stakeholders onboard, merge all innovative ideas, remove all information silos, connect all systems, understand all local and global needs, and make changes if required. There are different models to measure how successful organizations make digital transformations. The organization can generally measure the success of driving digital transformation through maturity levels. The maturity level is divided into different levels that, in almost all cases, mark level 1 as the beginning of transformation and level 5 or higher as the final stage of transformation [13].

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***** Correspondence Author (s)
Dr. Manish Shashi*, College of Management, Walden University, Minneapolis, MN, USA**.** Email: manish.shashi@gmail.com

However, most digital maturity model does not consider sustainability. There is a need to work on digital sustainability matric, which serves as a collaborative method to address any potential short-term or long-term undesired effects of technological usage during digitalization initiatives.

II. DIGITAL MATURITY AND SUSTAINABILITY

In an organizational context, the term maturity can be defined as the degree to which a process is defined, managed, measured, and continuously improved [4]. A digital maturity model is a valuable tool to access the supply chain's current state and guide it towards a better state of digitalization. Maturity models can also serve as the starting point for the digitalization process [14]. It may be complex to define a standard optimal digital maturity model as digitalization may affect all functional areas of the organizations. There are as many as twenty-eight maturity models identified during this study. Most models do not define zero level of maturity, but there may be cases when a digital transformation initiative has not been conducted yet [3]. Buntak et al. (2021) suggested six levels of digital maturity in the supply chain. Every level has different characteristics and levels of synergy between implemented technologies and humans or organizational systems with different risks. Buntak et al. (2021) suggested five indicators measured within the proposed model, such as (i) Conduction of digital transformation, (ii) Communication in the organization and between organizations within the supply chain, (iii) Creation of new business paradigms, (iv) Synergy in the organization and between organizations within the supply chain, and (v) new technologies used for processes optimization [3].

Gupta et al. (2020) proposed the Digitainability matrix, also knowns as the digital sustainability matrix (DSM), which serves as a means for collaborative methods to address any potential short-term or long-term undesired by technological usage. DSM tool may also help aid in systematically capturing transdisciplinary knowledge generated on several aspects, such as: (i) the need for research–practice nexus action; (ii) data-capturing efforts and social considerations; (iii) collaborative planning for utilizing the power of digitalization and (iv) lessons from the diverse community to encourage the purposeful use of technologies [9]. DSM in Figure 1 demonstrates two dimensions of the digitalization sustainability matrix: The vertical axis presents the sustainability digitalization goal (SDG), and the horizontal axis represents the Digitalization and artificial indicators (D & AI). The eight key digitalization technologies, such as mobile internet technologies and apps, blockchain, Internet of Things, big data, cloud, artificial intelligence, Augmented reality, and adaptive manufacturing, are grouped under three broad themes. Figure 2 was a DSM matrix translated from pre-poll events. For example, while discussing the relevance of mobile technologies for Indicator 13.1.1, participants pointed out the negative impact of mobile data by breaching users' privacy. Furthermore, the discussion also highlighted the negative relevance of VR/AR technologies for energy consumption and infrastructure needs (Indicators 13.1.1).

Table 1: Six levels of digital maturity (Buntak et al., 2021)

Maturity level	Description
0	Digital transformation is not conducted. The supply chain is traditionally organized. All communication is carried out by traditional ways that in most cases means using e-mails and documents. Level 0 also describes cases in which only one of the organizations within the supply chain conducted digital transformation but the organization can not use its advantage and implemented technology in full potential because other organizations are not implementing digital technologies.
1	All organizations in the supply chain conducted digital transformation but not enough to develop collaboration between each other. Communication is carried out with the help of the new system but in most cases organizations are using e-mails and traditional ways of communication. In each organization in level 1 maturity, the optimization of process and creating a new paradigm of business is carried out.
2	All organizations in the supply chain conducted digital transformation. Communication and collaboration between organizations are developed and carried out with new technologies such as cloud computing. Organizations are using drones to transport products. Warehouses are automated and the efficiency of warehouse processes is increased. Each organization has created new paradigms of business, and started creating synergy within the organization. Employees use new technologies as support for their tasks.
3	In each organization there is synergy between new technologies that are implemented and existing ones. Organizations are using IoT, blockchain, 3D printers, sensors, etc. for managing all processes. There is a start of creating synergy between all organizations within the supply chain. Organizations have significantly increased efficiency and significantly decreased costs of processes.
4	There is a synergy between all of the organizations in the supply chain. All organizations use technologies such as DT (digital twins) which create a digital copy of the physical system for optimizing and simulating processes. The supply chain is in the digital sphere. Artificial intelligence is used for analyzing and simulating risk and market demand. The need for human labor is decreased. The automated system is directed towards substituting humans in the system.
5	The supply chain is the digital transformation. There is no need for human labor. Humans are only needed for maintenance and fixing autonomous systems as well for programming it. Robots are carrying out all activities in the system. AI system is used for managing the entire supply chain with no need for human intervention. There is a risk of self-sufficiency of automated systems and eliminating humans from it.

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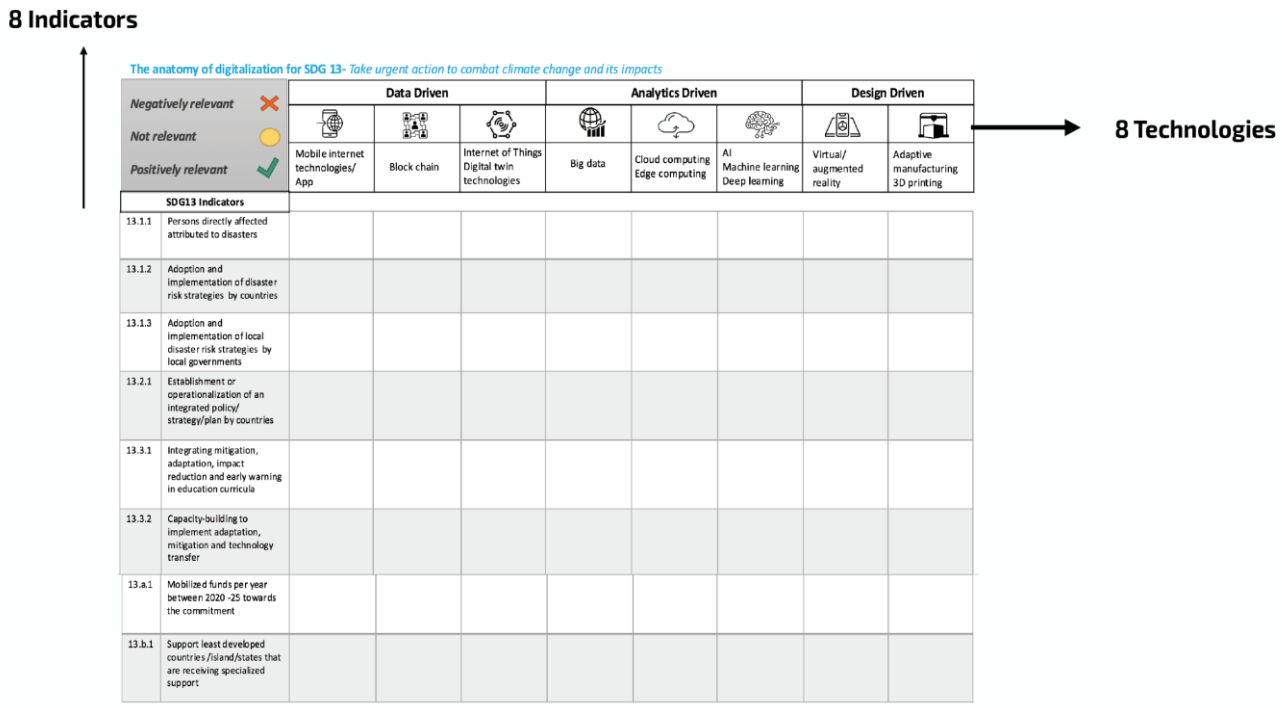

Fig. 1. Digitalization-Sustainability Matrix (Gupta et al., 2020)

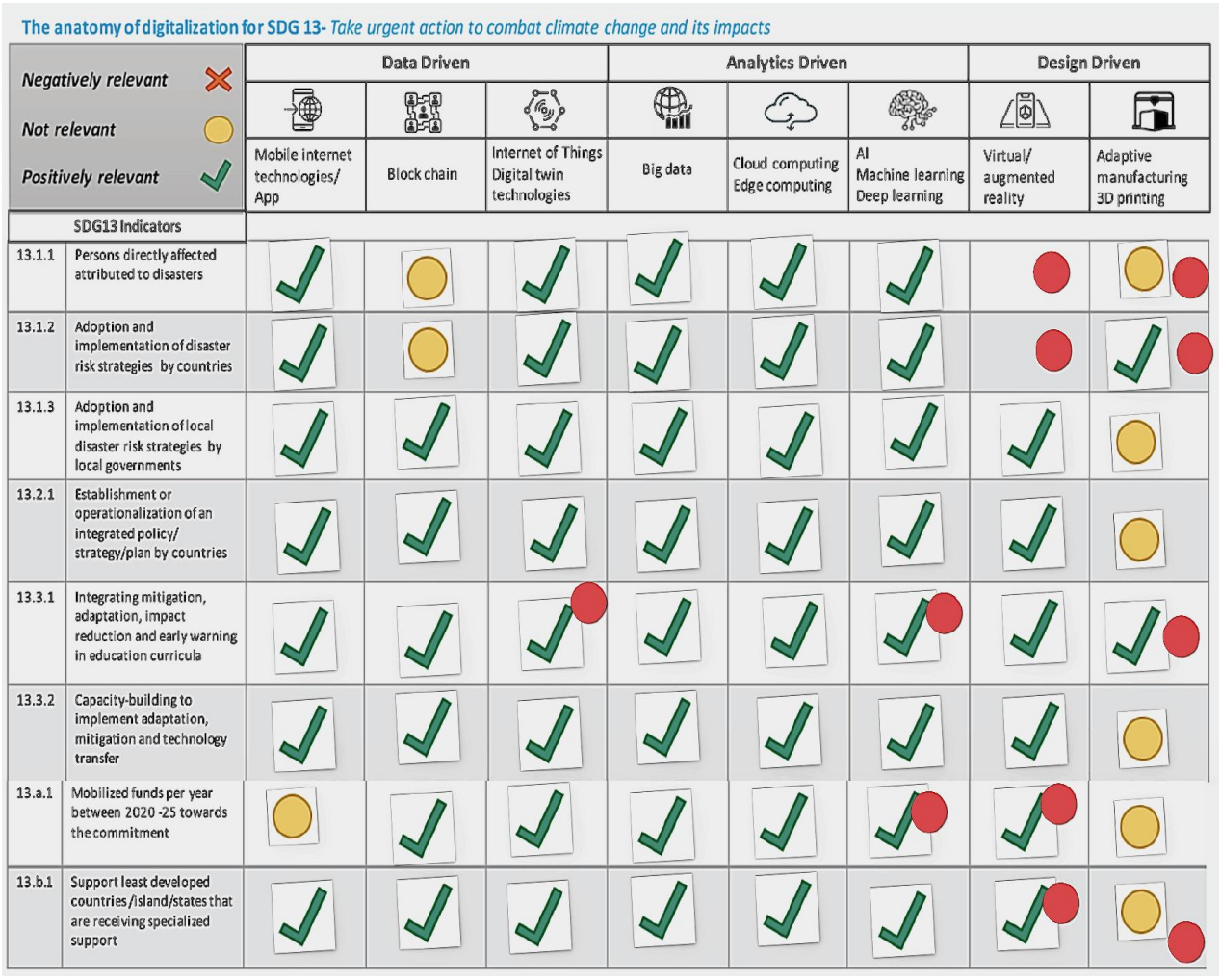

Fig. 2. Digitalization-Sustainability Matrix translated from the event (Gupta et al., 2020)

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III. LITERATURE REVIEW

Sustainability is protecting stakeholders' interests by focusing on non-financial environments, such as environmental, social, ethical, and governance, by accomplishing financial performance and creating stockholders' s value [20]. Sustainability is described as meeting the present's needs without compromising environmental generations to meet their own needs [11]. Gouda and Saranga (2018) found that organizations have adopted social and environmental sustainability practices to reduce their carbon footprints and improve their image on the social front [8]. Sodhi and Tang (2018) suggested that organizations that adopt sustainable practices in their supply chain processes outperform their competitors in stock market performance and financial metrics [19]. The manufacturing processes may consume energy and materials and, in the process, release waste also in the ecosystem [16]. Even the global supply chain's transportation process may adversely impact the environment regarding energy used [17]. Alzaman et al. (2018) noted that implementing green SCM will improve environmental performance regarding fewer carbon footprints and help the competitive advantages and economic performance of an organization [1]. Social sustainability in the supply chain also plays a substantial role, as supply chain managers and partners must address stakeholders' needs and human capital to achieve long-term sustainable results [16]. Digitalization can be understood as using digital technology, leading to change in value creation, business processes, and business models to provide new revenue and value-adding opportunities [6]. Digitalization facilitates the organization toward digital transformation by automating the processes for better outcomes [16]. Digital transformation is a fundamental change process enabled by digital technology that aims to bring radical improvement and innovation in an organization to create value for its stakeholders by strategically leveraging its resources and capabilities [7]. Digitalization of business processes enables organizations in various innovations, including improved design and new process models. It shapes how organizations create enhanced values for their business partners, such as customers and vendors [12]. The new digital technologies present essential threats to any organization and, at the same time, provide game-changing opportunities also [15]. An environmentally friendly green supply chain is a logistics network that distributes products from manufacturers to end customers (Ahmad et al., 2016). Green supply chain management aims to assess the environmental influence of various production and/or distribution approaches to reduce greenhouse gas (GHG) emissions through logistics activities [22] Hua et al. (2011) developed an inventory planning model that minimizes holding, ordering, and carbon emissions costs while determining the optimal order quantity considering the conventional economic order quantity (EOQ) [22]. Buying decisions of consumers globally are increasingly based on environmental sustainability factors [10]. It prompts organizations to promote environmental and digital targets addressing the sustainability digitalization goals and the fast development of digital technologies [10].

IV. DISCUSSION

The link between digital technology and digitalization is vital to create competitive advantages. Adopting the latest technology may not work unless sustainability factors, agility, and customer centricity are added. Digital transformation creates a digital business instead of a business that goes digital and does not survive and thrive in the digital age. There can be positive and negative impacts of digital technology on sustainability. Here are some green digitalization tools and technologies to incorporate for business:

1. **Internet of Things (IoT):** The IoT is a network of objects connected through the internet and able to collect and exchange data using embedded sensor technologies. The data helps objects to make intelligent decisions autonomously in real-time without any human interventions. It helps reduce wastage, for example, by reducing (and saving) humidity and temperature control parameters when transporting drugs in a cold supply chain system. Smart IoT-enabled sensors in a supply chain warehouse can help reduce 30% of GHG emissions by implementing smart sensor-based light and intelligent HVAC systems. Transportation accounted for 29% of US GHG communication, per a survey in 2019. Smart sensors like telematics can also help in tracking the condition of the vehicle, such as degradation in engine and tires, which creates inefficiencies and results in the consumption of more fuels

2. **Cloud:** The idea of consuming what we need is a common mantra in making a sustainable future, and the design of the cloud is inherent in that principle [2]. According to Accenture research, if all enterprises had used public cloud systems, annual GHG emissions would have been decreased by the equivalent of removing 20 million cars from the road. Computing resources are provided on demand, reducing the on-premises footprints associated with wastage in power consumption, cooling, and compute power [2]. The cloud platform can also help provide digital models and support analytics, otherwise possible with onsite servers only. A 2018 study revealed that the cloud solution is 98% more carbon efficient than the on-premises solution.

3. **Artificial intelligence (AI) and machine learning (ML):** AI and ML models can be used to create models for forecasting emissions and optimizing the supply chain's operational efficiencies. As per ORION efforts, AI/ML can help optimize the route by minimizing turns and reducing its overall routes by eight miles. It is equivalent to saving eight million gallons of oil annually and equivalents to reducing annual carbon impacts by eliminating 20 million cars from the road.

4. **Drones:** In any supply chain operations, last-mile delivery is a significant operational step that has long-lasting impacts on GHG emissions, customer satisfaction, and delivery costs. Drones can help reduce cost and GHG emissions by catering to all consumers in the area compared to traditional transportation methods.

V. CONCLUSION

The triple bottom line of sustainability includes social, environmental, and economic sub-dimensions. Sustainability in the supply chain creates a competitive advantage across all industrial segments. A digital maturity model is a valuable tool to access the current state of the supply chain and guide it towards a better state of digitalization. It does not guide towards sustainability goals, however. The digital sustainability matrix can help measure the Digitainability of an organization's sustainable development goals [9]. In most cases, strategies related to digitalization and sustainability operate independently and are driven by separate sub-organization in a decentralized and sporadic manner. Integrating both strategies can help (i) positive impact on supply chain performances, (ii) help in building brand equity and reputation, (iii) help in driving revenues, (iv) help in making economies circular by closing the loops of material and energy flow, (v) increase energy efficiency and decrease the negative impact on the environment by reducing waste and optimize resources, (vi) working with all stakeholders, and finally (vii) accelerating towards sustainability goals to make intelligent and smart decisions in their respective areas. Pullen et al. (2007) explained the maturity model as different maturity levels to assess the extent to which an object (an organization, a process) fulfills the defined requirements [14]. The three Rs to sustainability are recycling, reuse, and reducing, and the digital maturity model must consider these and make possible a more circular economy. The pressure on manufacturing organizations to adopt sustainability has increased significantly. The digital sustainability matrix helps organizations use green digital technologies toward implementing sustainable development goals.

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AUTHORS PROFILE

Dr. Manish Shashi is a global supply chain, senior leader, and researcher. Dr. Shashi has more than 28 years of experience working globally in more than 12 countries, including APAC, Europe, EAMER, and the Americas geographies. Dr. Shashi earned a mechanical engineering degree from NIT, Surat, MBA from DBIM, India, a Lean Six Sigma Black lack belt from Villanova University, PA, USA, a master's in management from Saint Elizabeth, NJ, USA, and a doctorate from Walden University, MN, USA. Dr. Shashi is also associated with MIT, the USA pertains to the digital transformation program.