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Port sustainable supply chain management framework: Contributing to the United Nations' sustainable development goals

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Abstract

Sustainability is a fundamental concept and, thus, is always placed in the center of business management, which includes 3 different dimensions: environment, economy, and society. Port supply chain management is no exception in encompassing these dimensions. Port sustainable supply chain management can be associated with implementing the United Nations' (UN) sustainable development goals (SDGs). Little effort has been made to shed light on this association. Therefore, an attempt is made in this study to build a framework that comprises measures for the port sustainable supply chain management. The measures are examined by the utilization of the "dashboard of 5 Ps" (Peace, People, Planet, Partnership, Prosperity) in order to identify how the framework measures can contribute to the achievement of the SDGs. Results show that ports have the potential to influence all of the SDGs, either directly or indirectly. Additionally, the framework can be viewed as a conceptual tool that is very appropriate for ports that aim to integrate economic and social aspects along with environmental concerns and push forward the implementation of the UN 2030 agenda, internally and externally, while collaborating with supply chains.

1. Introduction

Ports facilitate the handling and transfer of goods (and/or passengers) to hinterlands, as well as transshipment activities (Yap & Lam, 2013). Today, the volume of seaborne trade that is handled by numerous ports around the world is extremely important for the normal functioning of the world economy. In 2018, ships carried 11 billion tons of seaborne trade; the volume of seaborne trade expanded slightly by 0.5 % in 2019, down from 2.8 % in 2018, and reached 11.08 billion tons (UNCTAD, 2019). In addition, container traffic witnessed 2 % growth. A pattern of expansion is always projected, even in the presence of disruptions such as COVID-19 Pandemic (Clarksons Research, 2020).

In any case, with water covering almost 3 quarters of the Earth's surface, and well over 80 % of all international trade being transported via our planet's seas and oceans, shipping activities are rightly viewed as the backbone of the complex globalization phenomenon (Dalaklis, 2017). To meet the increase in seaborne trade volume in general, and in containers in particular, the number and size of ships have grown considerably over the years. Hence, many ports have invested in

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infrastructure and superstructure to improve the productivity of, and adaptation of their operations to, these developments (Dalaklis et al., 2020; UNCTAD, 2010).

However, this extraordinary growth of shipping and ports has also magnified certain environmental impacts, such as waste and noise, air, oil, and water pollution, and at the same time significantly increased the demand for energy (Alamoush et al., 2020; Lam & Notteboom, 2014; Theo et al., 2020). Quite often, port and shipping operations impact negatively on marine biodiversity and increase air pollutants (such as sulfur emissions) and greenhouse gases (such as carbon emissions), which are usually associated with climate change issues, health problems, and ocean acidification (Ölçer et al., 2018). Taking the shipping emissions side only, the third IMO GHGs study (Smith et al., 2014) estimated that shipping, through exhaust, emitted 3.1 % of global CO2 emissions between 2007 and 2012 and, particularly international shipping emitted 2.2 %. Dramatically, by 2050, shipping emissions may grow by 50 %, in line with the expected world trade growth (UNCTAD, 2015), as international shipping was not embraced within the international conventions on climate change mitigation, e.g., the Kyoto Protocol or the Paris Agreement. Nonetheless, if certain energy, technical, and operational measures were to be used, shipping emissions would be expected to be reduced by 25 - 75 % below such predictions (IMO, 2018).

Although the environmental impact of port activities has been frequently addressed (including shipping and land transport), port economics need to be addressed as well. Ports are also very powerful economic drivers for national economies and social cohesion for nearby communities and related employees since they can enhance and support various socioeconomic priorities. It is true that the concept of port influence and impact on the environment, economy, and society is engulfed in "port sustainability" (Cheon, 2017; Cheon et al., 2017; Laxe et al., 2017). However, as manifested by Lim et al. (2019), ports' economic and social impacts are not well addressed in the literature, e.g., revenues against investment, port efficiency, well-modernized port facilities, and port capacity. Despite this, the related literature review facilitates the identification of certain already-implemented measures- or proposes numerous new ones- to set ports on the right sustainability track. Unfortunately, these measures are only applied by front-runner ports in Europe, North America, and a handful of ports in Asia (Poulsen et al., 2018). In other words, implementation is not well-enforced by local or national regulation, in addition to the utilization of punitive and incentive measures.

The implementation of port sustainability measures is influenced by various factors. Firstly, by international regulations, such as the UN Convention on the Law of the Sea (UNCLOS), IMO's Conventions, like the International Convention for the Safety of Life at Sea (SOLAS), the International Convention for the Prevention of Pollution from Ships (MARPOL), and the FAL convention for trade facilitation, the Maritime Labour Convention (MLC 2006) for laborers' rights, and the World Trade Organization agreements and provisions, among others. In addition, there are regional and national regulations, such as those in the EU region and countries, e.g., EU directives and regulations, e.g. (EC) No. 2015/757 on monitoring shipping emissions. Secondly, by port authorities' policies and priorities, which are derived from local environmental, social, and economic (trade) regulations. Clearly, maritime stakeholders- like ships, hinterland transport, and shippers- contribute to port sustainability; their willingness is driven by international regulation, their corporate social responsibility, and economic and market-based measures, e.g., emission tax and various incentives.

Given these facts, the interplay of port sustainability involves measure identification in the 3 dimensions of sustainability, which encompass ports activities and maritime stakeholders, in addition to implementation schemes. Implementation schemes, i.e., tools that ports use to put the measures into actions (IMO, 2018), such as regulations, tariff changes, concession contracts, extra charges, and incentives, are out of the scope of this research effort; its focus is only on the identification of holistic sustainable measures of ports themselves. Furthermore, to have a complete

picture, based on the notion that sustainability stretches out beyond port boundaries, the direct supply chain of stakeholders is included.

To this end, motivated by the lack of research on port sustainable supply chain management and the importance of linking this to the sustainable development goals within port operations, we attempt to build a framework of various measures, which includes the economic, social, and environmental dimensions, as well as explain their contribution to the United Nations' Sustainable Development Goals (SDGs, 2030 agenda) (United Nations, 2015). The main goal of this framework is to provide port policymakers with an overview on various applicable measures. In addition, the specific framework can be utilized to map port potential to transit towards overarching sustainability. The next section presents the research outline, followed by the necessary literature review. Then, the methodology used is explained. The presentation of the results then takes place, followed by a concluding section.

2. Research outline

In this research, sustainable port supply chain management measures and sustainable development Goals (SDGs) are linked together. As summarized in **Figure 1**, the research schematic view, we review the literature related to supply chain and management in general, port supply chain management, sustainability, sustainable port supply chain management, actors in the supply chains, and the SDGs, to set up the overall area of the investigation. "Port sustainable supply chain management" is divided into port internal management and external collaboration with supply chain actors. Based on this, a framework of measures that encompasses internal management measures and external collaboration is built. The framework of measures is examined by the dashboard of 5Ps (which is fully explained in section 4, below) to identify the contribution of port sustainable supply chain management to SDGs.

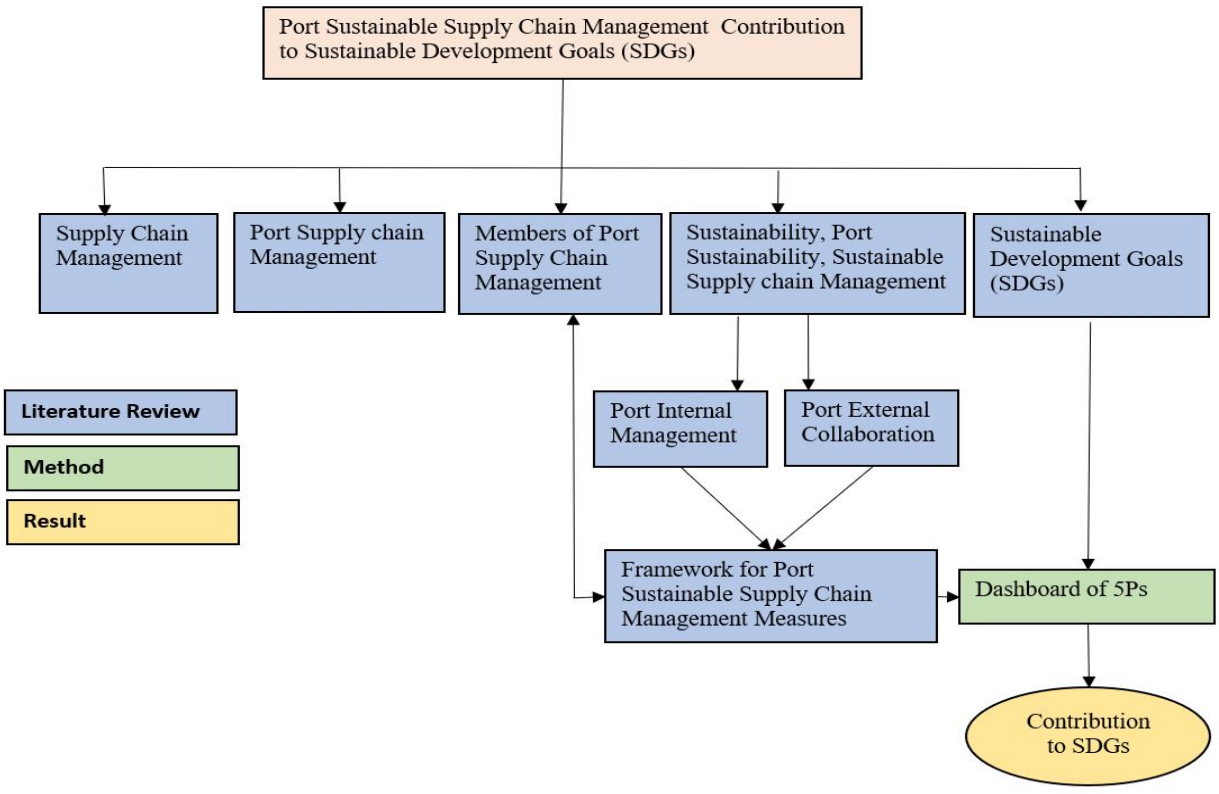

Figure 1 Research schematic view.

3. Literature review

3.1 Supply chain and supply chain management

The supply chain encompasses the parties involved- directly or indirectly- in fulfilling a customer request, i.e., manufacturers and suppliers, transporters, warehouses, retailers, and customers (Chopra & Meindl, 2007). Within each organization, such as a manufacturer, the supply chain includes all functions involved in receiving and fulfilling a customer request. These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service. The purpose of the supply chain is to maximize the overall value generated (profitability) and minimize the total cost of the associated activities. The supply chain is seen as a set of 3 main actors and different players, such as entities, organizations and individuals, all encompassed wholly, from the sources to the customers, in the upstream and downstream flows of products, services, finance, and information (Mentzer et al., 2001). Very briefly, a supply chain comprises 3 main players- the company that makes the production (the focal firm), the supplier, and the customers of the supplier, forming a simple or immediate supply chain (Mcmillan, 2008; Colin et al., 2011).

Mentzer et al. (2001) divided supply chain complexity into 3 aspects: first, the direct supply chain that describes a company, an immediate supplier, and the customer; second, the extended supply chain, which contains suppliers of the immediate suppliers and customers of the immediate customers; the third is the ultimate supply chain, which includes all the entities engaged in the supply chain upstream and downstream flows, from the first supplier to the very last customer. The ultimate supply chain may include a third, fourth, and fifth-party logistics provider (3,4,5PL) (Hosie et al., 2012). As a result, the notion of "Supply Chain Management" is introduced, which is a broader concept that integrates key business processes from original suppliers to end-users to improve the long-term performance of individual companies and the supply chain as a whole (Lambert et al., 2006; Mentzer et al., 2001). In the current research effort, the direct supply chain is addressed by approaching the port, including the operator, as the focal company that interacts with various supply chain actors, i.e., suppliers and customers.

3.2 Port supply chain management

Port supply chain is interchangeably referred to as logistics supply chain, service supply chain, port-oriented chain (Robinson, 2002), and hinterland transport chain (Horst & Langen, 2008). In this research effort, the port supply chain is viewed as the supply chain of goods and services, considering the port as a focal company that has its supply chain, with various other actors that are integrated within that supply chain. Customarily, ports are considered as integral parts of the transport system and a major sub-system of the broader production and logistics systems in the global supply chain (Bichou & Gray, 2004). Ports operate as nodes between sea and shore by providing calling ships with shelter and berths, short-term storage for cargo, infrastructure for operations, and cargo handling and transfer. Hinterland and inland transport are integrated with port supply chains (Gonzalez-Aregall et al., 2019). However, the development of supply chains supports market players and stakeholders in rethinking their roles in the logistics process and adapting to the challenges of ports as functional nodes in logistics and supply chain networks (Notteboom & Rodrigue, 2005). Conventionally, the concept of the port supply chain is perceived as involving tiers of suppliers and tiers of customers interacting with ports (Troisi & Tuccillo, 2015). In a wider concept, the "Port Supply Chain Management" is considered as "*the management of a port logistics chain that promotes the efficient integration and coordination of public and private stakeholders for planning, implementing and controlling the flow of maritime and land transport, cargo and information from origin to the point of destination, hinterland and foreland, in an efficient and effective way, in order to minimize system wide costs while satisfying service level requirements of importers and exporters* (Ascencio et al., 2014). Thus, port supply chains are highly interrelated with economic perspectives.

3.3 Port supply chain members

Bichou and Gray (2005) identified the members involved across a port supply chain, namely shippers, ocean carriers, port operators, and logistics operators. Activities performed by these members can be divided into 3 categories (Teurelincx, 2001). First, foreland activities, maritime transport, and maritime access; second, activities within the port sector itself, such as transshipment, warehousing, value-added logistics, manufacturing, forwarding, and distribution; and third, hinterland activities, such as road transport, rail transport, and inland navigation. Moreover, in their simulation study using a port supply chain, Lee et al. (2003) decomposed port supply chains into supply of products, materials, and services. Also, they indicated that "*a port management system consists of a ship-operation system, a cargo-moving system, storage systems, receipt and delivery systems, gate-operation systems, and management and operation information systems*". On the other hand, Robinson (2002) portrayed the port-oriented supply chain members, i.e., the shipping lines, shipping agents, stevedoring companies, customs agents, freight forwarders, rail operators, trucking companies, and depots. Furthermore, Robinson (2006) used the notion of port-oriented landside supply chains, which included different actors, such as port authorities, terminals, rail operators, trucking operators, and depots.

The hinterland transport chain, as asserted by Horst and Langen (2008) in the port of Rotterdam hinterland coordination, involves different supply chain members, such as shipping lines, container terminal operator(s), barge operator(s), road haulage, shippers, and public players, e.g., customs, the port authority, and inspection services. In addition, Martino et al. (2011) approached the port as a network of actors, resources, and activities that together generate value by way of promoting several interdependencies among the supply chains that go through the port. To this end, the actors of port supply chains have been widely discussed and confirmed in the literature. Based on the above, it is argued that the port supply chain is an experience created in combination with other actors, such as maritime administrations, shipping agencies, container depots, freight forwarders, customers, and carriers. Therefore, as summarized in **Table 1** below (and based on the literature review above), the port supply chain main members are customers, suppliers, and other stakeholders. All these identified actors are considered in the current research effort as the chain members. They are utilized in a framework building for sustainability measures in the direct supply chains of ports, i.e., the first tier supply chain. By doing so, ports expand the sustainability concept from the ports themselves to the supply chain activities beyond their boundaries.

Table 1 Categories of port supply chain members.

Customers	Suppliers	Stakeholders (public players)
Shipping lines / ocean carriers	Trucking companies	Investors
Terminal operators	Railways	Public policymakers
Shippers	Depots and dry ports	Communities and societies
Shipping agents		Customs agents and inspection services
Freight forwarders		Maritime administrations

3.4 Sustainability

The Brundtland Commission Report, "Our Common Future", defined sustainable development as "*the development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987). In addition, Basiago (1999) explained the notion of sustainable development via 3 conceptual pillars and under the term "Triple Bottom Line" (economic, social, and environmental aspect of sustainability). Numerous academics

and practitioners have applied the sustainability concept to connote the improvement and sustainment in nourishing economic, ecological, and social systems for humans (Mensah & Enu-Kwesi, 2018; Stoddart et al., 2011).

This circulated definition is vital because it involves the transformation and expansion of the environmentally-based concept of sustainability to a trade-off between the ecology-based concept and the social and economic perspective (Koberg & Longoni, 2019). Moreover, these substrates are integrated and interlinked among each other, as they are elements of a dynamic system, and they cannot be pursued in separation to boost further sustainable development. Sustainable environmental practices include environmental management systems and certifications, e.g., ISO14001, and social sustainable practices, including conformity with local labor laws and the adoption and pursuance of social standards such as ISO26000 (Koberg & Longoni, 2019).

It is also necessary to note that the United Nations Sustainable Development Goals (2030 Agenda) emerged as a solution to comprehensive global sustainability. There were various challenges in commitments to sustainability in past summits and conferences. The adoption of sustainability requires integrated solutions, and to address these efficiently, the SDGs of the 2030 agenda were introduced, as summarized in **Table 2**, below. Their main purpose is "*to eradicate poverty in all its forms and dimensions, combat inequality within and among countries, preserve the planet, create sustained, inclusive and sustainable economic growth and foster social inclusion*"; however, these efforts must be linked to each other, because they are clearly interdependent (United Nations, 2015). Thus, through a review of the SDG targets and indicators, the authors of this research divided these goals into 3 sustainability dimensions. **Table 2** shows the results, while colors refer to the triple bottom lines. The intention is to use the port sustainable supply chain management 3 bottom line measures and check how these measures contribute to the UN SDGs within the 3 dimensions, i.e., environment, society, and economy.

Table 2 Sustainable Development Goals of the 2030 agenda.

SDG	Objective
Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages;
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5	Achieve gender equality and empower all women and girls
Goal 6	Ensure availability and sustainable management of water and sanitation for all
Goal 7	Ensure access to affordable, reliable, sustainable, and modern energy for all
Goal 8	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient, and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts*
Goal 14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
Goal 15	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: (United Nations, 2015)

3.5 Port sustainability

It could be argued that sustainable ports are prepared to extend sustainability to the supply chain, and that being sustainable paves the way to overarching sustainability outreaches. Research has clearly approached port sustainability in a similar fashion to the general sustainability concepts: environmental, social, and economic. According to Lim et al. (2019), the 3 dimensions of sustainability interact all together, or in pairs, with **Figure 2** demonstrating such interaction. The port environmental sustainability minimizes the harmful impact that stems from port operation, ships, and land transport. Social sustainability improves quality of employees' life and benefits neighboring communities. Economic sustainability is associated with port economic performance, while simultaneously maintaining environmental and social sustainability.

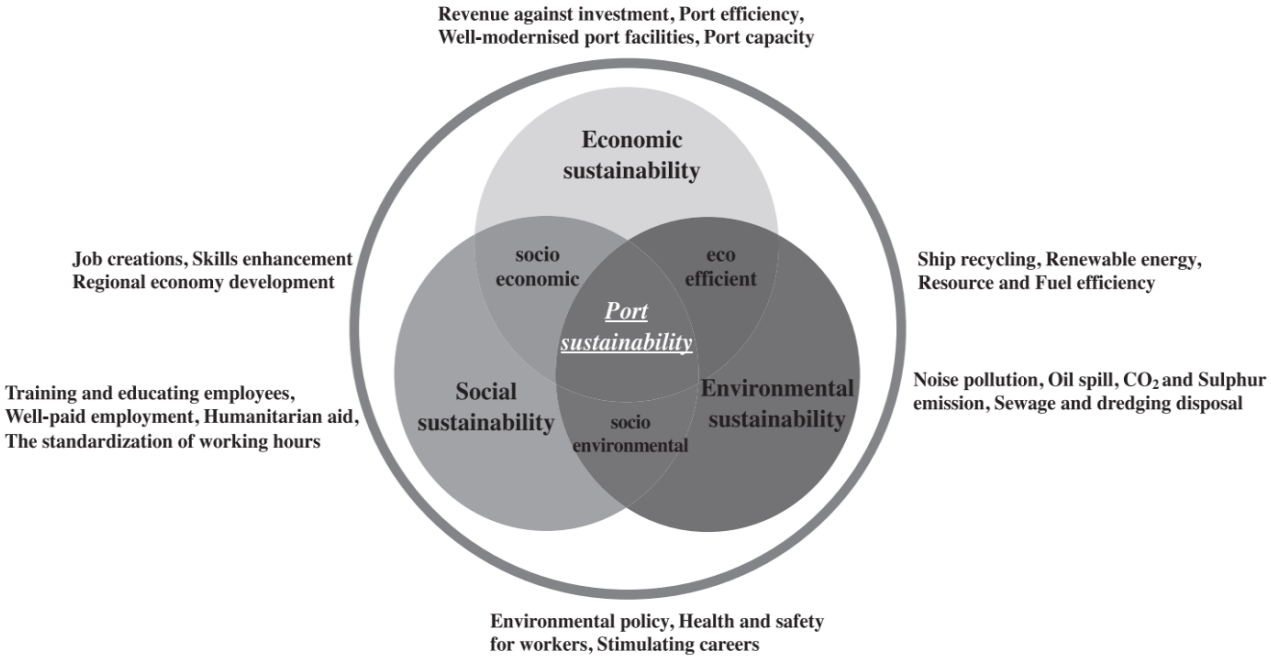

Figure 2 Interaction of port sustainability 3 bottom lines (pillars).
Source: (Lim et al., 2019)

3.6 Port sustainable supply chain management

Sustainability should be embedded therein port operations to provide sustainable supply chain management. The *sustainable supply chain* can be understood as the integration of business flow from the initial suppliers to the end customers in order to provide stakeholders with value-added products and services by employing sustainable operations. Lambert et al. (2006) introduced sustainable supply chain management as management that integrates business flows from the initial suppliers to the end customers to provide the stakeholders with value-added products and services by employing sustainable performance concepts. On the other hand, by factoring in the triple bottom line, Carter and Rogers (2008) defined *Sustainable Supply Chain Management* as "*the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains*". As clearly highlighted above, the sustainable supply chain reflects the economic, environmental, and social influence of an organization's activities on all its stakeholders, like all those affected by its activities (Larson, 2015). Under this notion, stakeholders are crucial in ensuring the sustainability of the supply chain. Nonetheless, *port sustainable supply chain management* is proposed to be management that integrates external port supply chain members, i.e., customers and

suppliers like seagoing vessels, or shipping companies, and assumes internal sustainable management, in which harbor crafts, cargo handling equipment, trailers, locomotives, and port services are included. This inclusion can help to accomplish the goal of sustainability in the triple bottom lines (Carter & Rogers, 2008; Gul & Cimen, 2012; Lu et al., 2010; Seuring & Müller, 2008; Shang et al., 2010; Zhu et al., 2007). Hence, all 3 dimensions of sustainability are required to be considered at the same time when evaluating port sustainability performance (Seuring & Müller, 2008; Shiau & Chuang, 2013). In brief, the concept of port sustainable supply chain management (the focus of this research) involves the port internal sustainable management, and the members of a port supply chain (identified in section 3.3), i.e., the suppliers, customers, and other stakeholders in external collaboration management. The internal sustainable management entails building sustainable measures by the port internally, in addition to other measures, to accommodate the requirements of the supply chain members sustainably. On the other hand, port external collaboration management encompasses sustainable measures taken up by supply chain members once they interact with the port, that is, to contribute to port area sustainability. Ports, therefore, may incentivize supply chain members, hold agreements, and apply regulations and standards to improve their collaboration to achieve wider sustainability. In **Figure 3** below, the framework for port sustainable supply chain management measures is demonstrated. The next step is to identify the measures that can be applied to the framework parameters.

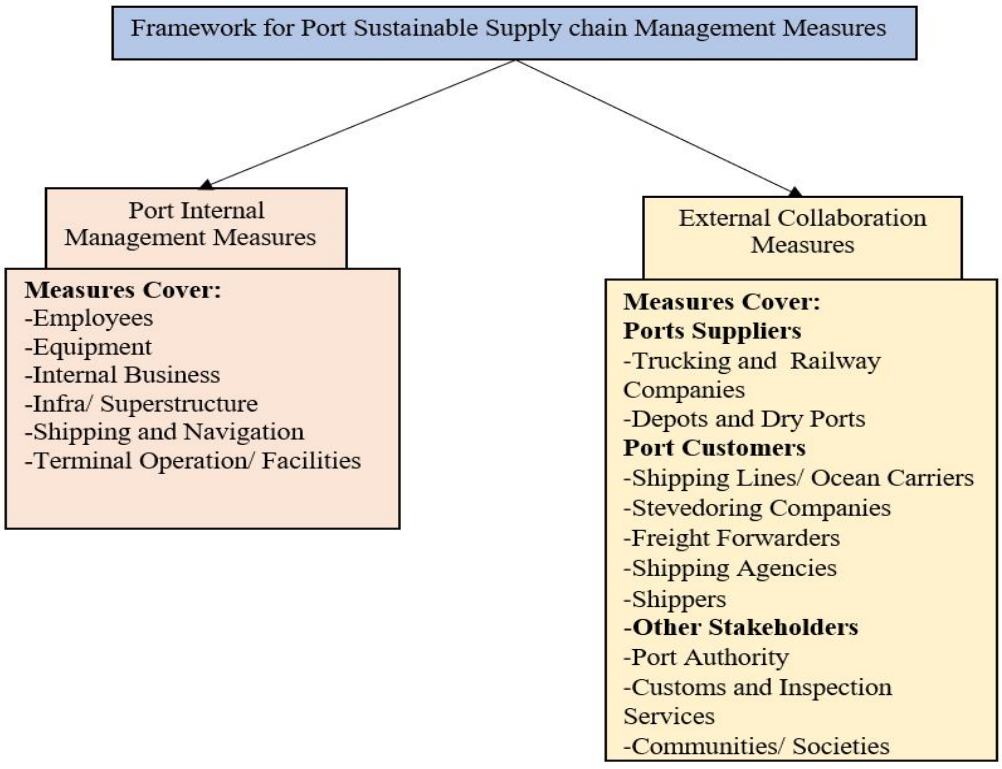

Figure 3 Framework for port sustainable supply chain management measures.

4. Materials and methods

In this section, we explain how port sustainable supply chain measures contribute to SDGs. The contribution of the measures relating to the framework of the SDGs will be examined through the sustainability dashboard of 5 Ps (Peace, People, Prosperity, Planet, Partnership), similar to the methodology that many ports use when they report the sustainability of the port and the SDGs achieved by these measures, as described for example in the Port of Antwerp Sustainability Report (Port of Antwerp, 2017). The 5 Ps are presented in **Figure 4** and correspond to the pillars of the 17 SDGs (Global Development Research Center, 2015). Thus, achieving the UN 17 SDGs results in

many ecological, social, and economic consequences that are inter-related (Singh et al., 2018)[†]. Therefore, we consider that an efficient and sustainable approach will undoubtedly contribute to achieving the 5 Ps eventually, especially if the fact that all SDGs are interdependent and connected in some way is considered. In other words, achieving one goal for the environment (planet) would contribute to achieving some of the other Ps and, ultimately, contribute to the all SDGs.

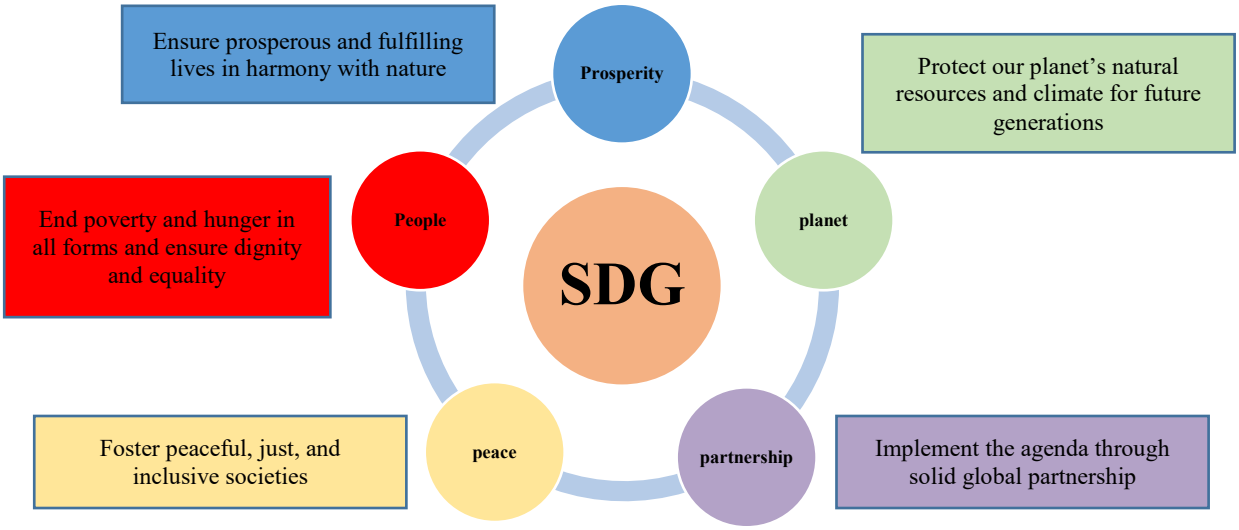

Figure 4 Dashboard of 5 Ps.
Source: (Global Development Research Center, 2015)

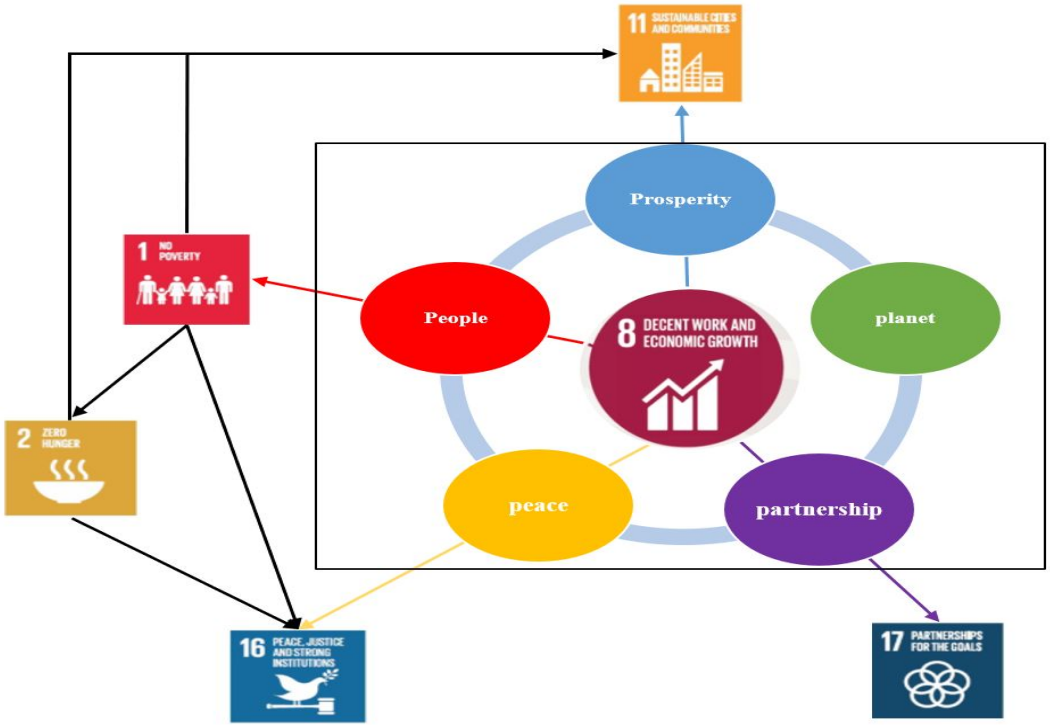

Figure 5 Method of finding the contribution of a measure to the SDGs.

[†]The authors built a framework that focuses on how SDG 14 (Life Below Water), and the targets within that goal, contributes to other SDG goals. In this study, we consider how all of the port sustainable measures contribute to the SDGs.

The sustainability dashboard of the 5 Ps is utilized (**Figure 5**) to critically identify the contribution of port sustainable supply chain measures (as in the next section) in achieving the SDGs. Certainly, a measure that is used to achieve port sustainability achieves an SDG. So, this SDG can be placed in the middle of the dashboard, and is used to think how that goal may contribute to achieving other goals from the dashboard method perspective. Such analysis and interpretation is based on the literature and researchers' expertise in the same field.

The example in **Figure 5** above explains the contribution of the measure of employees' welfare (health, salaries). This measure would directly contribute to Goal 8 (good jobs and economic growth), which is placed in the middle of the dashboard. If we can think about other Goals that would be triggered by having achieved Goal 8, they would include Goal 1 (decreasing poverty), which triggers Goal 2 (take actions against hunger). On the other hand, Goal 8 influences Goal 11 (help communities in port cities be resilient and have economically viable employees); the same is true regarding Goal 16 (having peace through societies because of lack of theft and fight), and Goal 17 (strengthen the means of implementation of the goals). Moreover, achieving Goal 1 and Goal 2, of course, contributes to Goal 11 (having sustainable communities) and Goal 16 (peaceful societies). This example, indeed, shows how all of the SDGs are interdependent and interlinked; if a goal is achieved, other goals are triggered. All of the measures that were chosen (in the next section) for the framework for ports to achieve sustainable supply chain management would be addressed similarly.

5. Port sustainable supply chain framework of measures and contributions to SDGs

Various tools address the environmental management in ports by utilizing environmental measures, e.g., Self-Diagnosis Method (SDM), the Port Environmental Review System (PERS), the Eco-Management Scheme and Audit Scheme (EMSAS), the ISO 14001 and, more importantly, the Environmental Management Systems (EMS) (ESPO, 2012; ESPO, 2018). Many sustainability tools for large seaports have been widely developed and elucidated since the nineties, as put forward by various academics and researchers (Darbra et al., 2004; Dinwoodie et al., 2012; Peris et al., 2005; Puente-Rodrıguez et al., 2016). Nonetheless, previous studies have taken on the green initiatives as the green port and logistics, which emphasized the environment and economic performance without the social aspect, e.g., Seuring & Müller (2008).

Environmental performance indicators were identified in 3 categories that can be referred to as *operational* (e.g., dust, noise, dredging, and waste), *managerial* (e.g., certifications, compliance, and complaints), and *environmental condition* (e.g., air, water, sediment, and ecosystems) (Puig et al., 2014). Various studies have addressed ports' environmental and sustainable management (Asgari et al., 2015; Bjerkan & Seter, 2019; Darbra et al., 2009; Gilman, 2003; Gul & Cimen, 2012; Kang & Kim, 2017; Lim et al., 2019; Lu et al., 2010; Peris et al., 2005). For instance, Gul and Cimen (2012) pointed out that the achievement of port sustainability is throughout the organization itself and through cooperation and collaboration with port supply chain partners, e.g., ocean carriers, terminal operators, truck companies, railways, stevedoring companies, and depot operators; that is, the port suppliers and customers. Peris et al. (2005) built a sustainable environmental management system for port authorities; Shiau & Chung (2015) suggested 36 port sustainability indicators for port operators (Keelung Port case), covering the 3 dimensions of economic, social, and environmental; Acciaro et al. (2014) modelled a framework for evaluating the environmental sustainability of ports; Lam (2015) addressed a sustainable maritime supply chain based on the quality function deployment approach; and Laxe et al. (2017) built a synthetic index of sustainability for 23 Spanish ports. In addition, the European Sea Port Organization (ESPO) listed Europe Ports' environmental priorities (Pravianen, 2019). The ports' technical and operational measures to reduce GHG emissions and improve the overall energy efficiency were reviewed (Alamoush et al., 2020). Measures spanned the portside operation in addition to shipping and hinterland transport interfaces.

In order to build the framework, measures from the studies discussed in this same section have been identified. These measures often overlap; a certain number of them had already been implemented, and others had only been proposed. However, owing to the goals of this study, the measures, regardless of whether they had already been implemented or not, were selected in order to build a holistic framework, where any port may evaluate the potential of implementation dependent on the port status, i.e., management, geography, function, throughput, economy, etc. This framework is divided, as previously explained, into port internal sustainable management actions and measures and port external collaboration. By doing so, ports achieve the sustainable development goals (SDGs). **Table 3** below summarizes the measures selected for internal sustainable management actions, the sustainability dimensions that the measures cover, and how these measures contribute to the UN SDGs. Their contributions are examined by the dashboard of 5Ps, which includes the direct impact and any other impacts that are triggered, next.

Table 3 Internal sustainable management measures.

Target Sustainability Dimensions	**Internal Sustainable Management Actions**	**Measures (Port Side)**	**Contribution to SDGs**	
			Direct	**Other**
Environmental	Shipping activities	Ballast water treatment facilities	14	3
		Access to clean energy	7	3, 12,13,15
		Waste reception facilities	14	3,15
		Emission reduction tools, technologies, and plans	13, 3	9,
		Reduction of ship turnaround time	8	3, 13
Environmental and Social	Transport activities	Sustainable mobility for employees	11	3, 15, 13
		Modal shift from truck to rail	13	3, 9,11,15
		Port's truck emission reduction	3, 13	9, 11, 15
		Reduction of truck waiting time (congestion)	3, 8	13, 15
		Improvement of infrastructure and safety promotion	9	3, 11
Social	Employees	Employee welfare (health, salaries)	1	2,3,8,11,16
		Employee health checkup	3	8, 11, 16
		Work security and safety (fewer accidents, etc.)	3	8, 11, 16
		Education and training	4	17
		Gender equality and diversity	5	10, 16
Economic and environmental	Economic generation	Cargo handling improvement (efficiency)	8	3, 9, 13
		Investment in ports	8	11
		Value-added logistics (activities)	12	9
Environmental and Social	Nature and environment protection	Litter control mechanisms	6	14
		Soil pollution monitoring	13	
		Monitoring of water quality	14	
		Air quality monitoring (SO2, NO2, PM, etc.) and emission reduction	3, 13	11
		Noise reduction mechanisms	3	14, 15
		Oil spill controls and mechanisms	14	15
		Nature conservation (protection of habitats, biodiversity, conservation areas, establishments)	7	11, 13
		Recycling	6	9, 12

Target	Internal	Measures (Port Side)	Contribution to SDGs	
Social	Surrounding societies	Examining societal issues with ports (questionnaires, customer satisfaction)	3	11, 16
		Support of local employment and trade	8	1, 2
Environmental and Social	Security	ISPS code application	8	11,16
		Disaster and incident controls and plans	11	8
		Hazardous materials and dangerous goods handling and storage plans (phosphate dust, chemicals, etc.)	3	14,15
Environmental	Renewable energy utilization and energy efficiency	Energy consumption control plans	7,12	13,3
		Renewable energy use (wind, solar, ocean)	7	13,3
		Energy-efficient super/infra-structure and port equipment	11	7,13
		Sustainable infrastructure, superstructure, and equipment	7, 11	13
Environmental	Climate actions	Greenhouse gas emission control and monitoring (indicators) (CO2, CH4, N2O) of ports and supply chain members	13	3,15
		Port plans for adaptation to climate change	13	9, 11
Social and Economic	Innovation	Technological development	9	8
		Investment in research	9	8
		Use of electronic data interchange (EDI), single window, port community system with supply chain members	8	9,17

SDGs: **SDG 1**: Poverty, **SDG 2**: Food security**, SDG 3**: Health wellbeing, **SDG 4**: Education, **SDG 5**: Gender equality, **SDG 6**: Water quality, **SDG 7**: Accessible, sustainable, & clean energy, **SDG 8**: Economic growth and employment, **SDG 9**: Infrastructure, innovation, and industrialization, **SDG 10**: Reduction of inequality, **SDG 11**: Sustainable cities, **SDG 12**: Sustainable consumption and production, **SDG 13**: Climate change, **SDG 14**: Life below water, **SDG 15**: Terrestrial ecosystems, **SDG 16**: Peaceful and inclusive societies, **SDG 17**: Partnership

The other part of the framework is the external collaboration measures and actions for members of the port supply chain, as presented in **Table 4**. We exhibit the measures that the chain members need to adapt to achieve sustainable development throughout their routine operations, and once interacting with the port, to eventually maintain sustainable performance. Like the internal sustainable management actions, the contribution of the measures to the UN SDGs is included. The measures and actions in **Tables 3** and **4** are not explained in detail, i.e., what is required from implementation of the measures in question. However, in the following section, measures are explained, in addition to interaction with the SDGs.

Table 4 External collaboration measure and actions.

Target Sustainability Dimensions	Port supply chain members	Actions & Measures	Contribution to SDGs	
			Direct	Other
Environment and Economic	Shipping lines/ ocean carriers	Emission control and reduction: -Compliance with international environmental regulations -Alternative cleaner fuel -Enrollment in environmental shipping indices	13,3	

Target Sustainability Dimensions	Port supply chain members	Actions & Measures	Contribution to SDGs	
			Direct	Other
		Emission reduction technologies such as scrubbers for SOx and PM, Selective Catalyst Reduction for NOx	11, 3	9, 14
		In-port ship waste discharge	14	3
		Ballast water treatment technologies	14	
		Utilization of communication technologies such as use of electronic data interchange (collaboration with the port, applicable to all supply chain members)	8	3, 11
Social, Environment and Economic	Freight forwarders, shipping agencies. customs agents, and inspection services	Safety and security of employees (while working within port)	3, 8	11
		Emission control mechanisms (in transport vehicles)	3, 13	13
		Efficiency improvement	8	12
		Employee sustainability training	17	
Social, Environment and Economic	Trucking companies and inland waterways	Safety and security of employees	3	8, 11
		Emission reduction technologies	13	3
		Emission control mechanisms		
		Efficiency improvement (reduction of turnaround time and idling)	8	13
		Decrease of traffic congestion in cities		
Social and Economic	Railways	Safety and security of employees	3	11
		Efficiency improvement (increase in rail throughput)	8	12
Economic and Environmental	Depots and dry ports	Multimodal transport facilities	8	9,12
		Emission control mechanisms	13, 3	
		Sustainable infrastructure and superstructure	9	
Social	Maritime administration	Monitoring of port safety and security	9	11
		Safe, secure, and sustainable navigation	14	3, 9, 16
		Research and innovation	8	9
Environment and Economic	Shippers	Use of sustainable shipping materials	11	15,12
		Sustainable import and export (Just In Time (JIT))	8	3,13
Social	Communities and Societies	Participation in port decision making and cooperation with port operators and port authorities	11	17

SDGs: **SDG 1**: Poverty, **SDG 2**: Food security**, SDG 3**: Health wellbeing, **SDG 4**: Education, **SDG 5**: Gender equality, **SDG 6**: Water quality, **SDG 7**: Accessible, sustainable, & clean energy, **SDG 8**: Economic growth and employment, **SDG 9**: Infrastructure, innovation, and industrialization, **SDG 10**: Reduction of inequality, **SDG 11**: Sustainable cities, **SDG 12**: Sustainable consumption and production, **SDG 13**: Climate change, **SDG 14**: life below water, **SDG 15**: Terrestrial ecosystems, **SDG 16**: Peaceful and inclusive societies, **SDG 17**: Partnership

5.1 Internal sustainable management measures contribution to SDGs

It may be argued that a port is not a country, so does not contribute to SDGs directly; however, ports are economic driver for countries, often have numerous employees, and consist of extended number of multiplier effects, e.g., thousands of ships, rails, and trucks calling ports and generating profits. In other words, "firms with a global presence struggle to improve environmental, social and economic outcomes in global supply chains" (Koberg & Longoni, 2019). Ports are considered a source of pollution along with having other positive social and economic impacts. Therefore, any contribution to sustainable performance, even in this marginal sector, still influences and contributes to the UN SDGs. As already highlighted, internal sustainable management refers to port measures for port operations, in addition to preparation of the supply chain members, in terms of sustainable measure accommodation.

5.1.1 Shipping activities

- *Ballast water treatment facilities*: Calling ships may come to port loaded with ballast water to stabilize the ship while it is not loaded with cargo. Ports offer treatment facilities which can be used instead of dumping water into the ocean, and this contributes to the quality of the ocean and sea water. Ships do not discharge ballast water that contains invasive species and pollutants, and this action contributes directly to Goal 14 (life below water) and Goal 3 (good health) (considering that unhealthy fish will, in the long run, negatively impact peoples' health).
- *Access to clean energy*: If calling ships gain access to clean energy, such as an onshore power supply, particularly from solar, wind, ocean, or biomass power electricity, this would contribute directly to Goal 7 (renewable energy) and Goal 3 (good health), because there will be fewer emissions from shipping at ports; hence, fewer health impacts on employees and societies. However, this measure triggers other goals, such as Goal 13 (climate actions), by having fewer GHG emissions, Goal 15 (life on land), and Goal 12 (sustainable consumption and production), i.e., responsible consumption with the lesser fuel consumption.
- *Waste reception facilities*: This measure directly contributes to Goal 14 (life below water) as the wastes of ships are collected at ports (in dedicated facilities) and are not discharged in the water. Then, it triggers Goal 3 (good health), i.e., the food of people (fish and other nutrients) sourced from seas are not polluted by waste. Moreover, the biodiversity and life on land of Goal 15 are sustained, because the waste may be prevented from affecting birds or animals on beaches.
- *Emission reduction tools*: This measure contributes directly to 2 goals, Goal 13 (climate actions) and Goal 3 (good health), by controlling the number of emissions that have impacts on peoples' health or climate change, such as GHG emissions. Moreover, this measure is a sign of achieving Goal 9 (innovation, and sustainable industrialization).
- *Reduction of ship turnaround time*: This measure contributes to the achievement of Goal 8 (economic growth) by having an efficient logistics chain, which provides more economic revenues and attracts more shipping lines due to operational efficiency preference. On the other hand, this measure contributes to achieving other goals, i.e., Goal 3 (good health), because ships emit less in the port, and Goal 13 (climate actions), because ships consume less fuel, which decreases the number of GHG emissions.

5.1.2 Transport activities

- *Sustainable mobility for employees*: This measure contributes mainly to Goal 11 (sustainable cities and communities). By having sustainable transportation for employees, city sustainability improves, i.e., less pollution. Other goals are triggered, such as Goal 3 (good health), due to less pollution, and Goal 15 (life on land) due to less pollution of SOx or NOx, which may cause acid rains and deteriorate plants and animals. Similarly, it contributes to Goal 13 (climate actions).

- *Modal shift from truck to rail:* This measure contributes to Goal 13 by maintaining actions to mitigate climate change. Changing trucks that burn fossil fuels and emit pollutants to more energy-efficient railways (which use electricity) is vital. Fewer emissions and less congestion in cities and ports contribute to the achievements of Goals 3, 9, 11, and 15. Health problems of societies become fewer, transition to sustainable cities and innovative infrastructure occurs and, of course, life on land is less compromised by truck pollution.
- *Port truck emission reduction:* Similar to the above measure, this measure attempts to control the emissions of port trucks, by either after treatments or retrofits. This contributes to Goal 3 (good health) and Goal 13 (climate actions). It also helps in achieving other goals, such as Goal 9, by having innovation implemented, Goal 11, by having sustainable cities free of air pollutants, and Goal 15, by improving the life of flora and fauna.
- *Reduction of truck waiting time (congestion):* This measure translates into fewer emissions in ports and cities. Ports may implement truck appointment systems for pre-booking, extend operational hours, and incentivize trucks to call at ports during non-peak hours. With that, Goal 3 is achieved (good health of the people), as is Goal 8 (economic growth), by sustaining efficient transport chains. Also, this measure contributes to achieving Goal 13 and Goal 15 (climate actions and life on land, respectively).
- *Improvement of infrastructure and safety promotion:* This measure contributes directly to Goal 9 (infrastructure, innovation, and industrialization), by having better infrastructure and road networks, and to Goal 3 (health), that is, by having better safety and health promoted and enhanced, e.g., training and certifications; thus fewer accidents happen, so there are fewer health problems, eventually contributing to the sustainable cities concept, i.e., Goal 11 (improved infrastructure).

5.1.3. Employees

- *Employee welfare (health insurance, salaries):* This measure contributes to Goal 1 (poverty). Employees are part of society, and having jobs decreases poverty. We could argue here that this also improves the economy of the society around A port, thus contributing to Goal 2 (less hunger), Goal 8 (good jobs), and Goal 3 (good health), because employees enjoy health insurance. Similarly, it triggers Goal 16 and Goal 11 by having a peaceful and economically stable society that has fewer problems and thefts.
- *Work security and safety (fewer accidents):* This measure attempts to improve the safety and security of employees; Goal-3 is achieved, thus, employees enjoy good health. Moreover, the good jobs provided (Goal 8), lead to sustainable communities (Goal 11) that enjoy peace and tranquility (Goal 16).
- *Education and training:* Ports offer education and training courses for employees and train them either in their specific fields or in sustainability awareness, which achieves Goal 4 (quality education) and Goal 17 (as this shows a partnership in achieving the SDGs).
- *Gender equality and diversity:* Gender equality in maritime transport, which is male dominant, is fundamental; thus, having this measure contributes to Goal 5 (gender equality), by giving chances to both genders to have jobs in ports. Also, this measure reduces inequality in societies (Goal 10). Of course, having satisfied people and fair treatment among genders will promote peace and justice (Goal 16).

5.1.4 Economic generation

- *Cargo handling improvement (efficiency):* This measure contributes directly to Goal 8 (economic growth). If freight handling is improved by having efficient operations, efficient cargo handling equipment, and integration with public private partnerships, economic revenues increase. Also, this measure triggers innovations (Goal 9). Additionally, Goal 13 (climate change) and Goal 3 (health) are promoted because efficient cargo handling means that ships and trucks will not stay at

port for a long time, meaning less congestion and fewer emissions, ultimately leading to fewer health problems.

- *Investment in ports:* Investing in better port infrastructure, superstructure, cargo handling, expansion, digitalization, etc., improves port economic revenues**.** The main goal this measure contributes to is Goal 8 (economic growth). Then, it contributes to Goal 11 (sustainable cities and communities) that enjoy the economic revenues which come from port investment.
- *Value-added logistics (activities):* Ports may engage in logistics activities, such as the case of containers, cars, and goods packaging, assembling, tagging, and other services. Similar to the above measure, the main goal this measure contributes to is Goal 8 (economic growth). Then, this measure contributes to Goal 11 (sustainable cities and communities), enjoying the economic revenues that come from port value-added activities. The economic situations of ports improve owing to the new services offered to ships, ultimately increasing the number of employees.

5.1.5 Nature and environment protection

- *Litter control mechanisms:* This measure contributes to cleaner water and sanitation (Goal 6). Reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials into water improves water quality in close rivers and reservoirs. Once the litters of port activities are collected, the trash and particles do not enter the sea, which keeps life below water intact (Goal 14).
- *Soil pollution monitoring:* Port activities impacts on soil from the litters, chemicals, and dust, and even air pollutants, that could get into the soil of port land or outside. Having such a measure contributes to achieving Goal 13 (life on land).
- *Monitoring water quality:* This measure means observing and monitoring the quality of the water around ports and the sea. Ports check how emissions and spills affect the water. This goal contributes to Goal 14 (life below water).
- *Air quality monitoring (SO2, N_2O, PM) and emission reduction:* Ports dedicate various tools to reduce emissions from their activities. They would start with emission inventories to establish base line years of emissions, track and monitor the emissions through various technologies, then apply emission reduction measures, such as pre- and after-treatment retrofits and energy storages for cargo handling equipment, eco driving, eco crane handling, the use of alternative fuels, and the electrification and hybridization of equipment, among others. This measure contributes to Goal 3 (good health) and Goal 13 (climate actions). Eventually, having less polluted port cities participates in establishing sustainable cities and communities (Goal 11).
- *Noise reduction mechanisms:* With less noise at ports, fewer health problems occur; thus, Goal 3 is sustained, and this provides good and convenient jobs for port employees (Goal 8).
- *Oil spill controls and mechanisms:* Ports, either operators or authorities, are required to have plans and assets ready to prevent and respond to oil pollution from shipping accidents. This measure contributes directly to protecting life below water (Goal 14) life on land (Goal 15), because oil spills, most of the time, end up on beaches and coasts where plants and habitats are highly harmed. When major oil spills occur, tourism sector revenues drop, and the fishing market deteriorates.
- *Nature conservation:* Part of port corporate social responsibility and commitment to the environment which might be harmed by port activities; ports can engage in the protection of habitats and biodiversity and establish conservation areas in the vicinity of ports. These measures contribute to biodiversity being protected at sea, and nature on the seabed is conserved (Goal 14). Also, nature on land is protected (Goal 15).
- *Sustainable infrastructure, superstructure, and equipment*: By having sustainable infra and superstructure and equipment, energy conserving buildings dependent on cleaner alternative fuel, and/or renewable energy (e.g., solar, geothermal, ocean, and wind energy) Goal 7 (renewable

energy) is contributed to. Moreover, this measure contributes to other goals, such as Goal 11 (sustainable cities) and Goal 13 (climate change mitigation).

- *Circular economy:* when ports reuse and recycle access materials through recycling facilities, this decreases the amount of waste thrown into the environment; this contributes to Goal 6 (water quality), Goal 12 (responsible consumption), and Goal 9 (innovation and industrialization). To achieve this, ports may source recycling, integrate with cities, or invest in in-port recycling facilities.

5.1.6 Surrounding societies

- *Examining societal issues with ports (questionnaires, customer satisfaction):* Applying such a measure, i.e., the inclusion of societal needs in port sustainable management, is critical in order to have better health for society and make cities and human settlements more sustainable, Goal 3 and Goal 11 are achieved, respectively. Societies can efficiently deliver their complaints when ports give them this opportunity via port city integration. Moreover, such measures enhance peace among societies (Goal 16).
- *Support local employment and national trade***:** Ports are pillars in world trade; additionally, ports create employment where a country's citizens can enjoy working with ports directly or indirectly (through the multiplier effect). By this, Goal 8 is promoted (sustainable economic growth), which offers full and productive employment and decent work for all. Moreover, maintaining good trade traffic improves the economy, and promotes Goal 1 (less hunger) and Goal 2 (less poverty), by upholding a sound frequency of import and export trades.

5.1.7 Security

- *ISPS code application:* This measure contributes to Goal 8 (sustainable economic growth), as well as Goal 11 (make cities and human settlements inclusive, safe, resilient, and sustainable). The safety and security of ports and calling ships and rails are essential to continue economic trade peacefully. Implementing such measures promote peace in societies (Goal 16).
- *Disaster and incident controls and plans:* Contingency plans that make ports resilient to natural disasters, e.g., flood, fires, earthquake, epidemics, and pandemics, are important, particularly when ports train staff and employees on proper responses. In this measure, Goal 8 (sustainable economic growth) and Goal 11 (make cities and settlements safe and resilient) are enhanced; thus, sustainable cities are promoted.
- *Hazardous material handling and storage plans:* If hazardous material is handled properly, as planned, less risk or threat, such as fires, spill over water, etc., may be the effect and this promotes Goal 3 (good health), Goal 14 (life below water), and Goal 15 (healthy ecosystem).

5.1.8 Renewable energy utilization and energy efficiency

- *Energy consumption control plans, and energy-efficient port equipment:* Ports establish energy management plans to control energy consumption, that leads to dependence on renewable energy (Goal 7) and promotion of sustainable consumption and production patterns (Goal 12). To improve energy efficiency, ports utilize energy efficiency measures in buildings and cargo handling equipment, e.g., the use of LED lights, energy saving tires, air conditioning and heat monitoring, automatically adjusting sensors, etc. It could be argued that less consumption of fossil fuel leads to fewer emissions, which promotes Goal 3 (good health) and Goal 13 (climate actions).
- *Renewable energy use (wind, solar, ocean):* This measure decreases dependence on fossil fuel and increases dependence on renewable energy. Ports utilize photovoltaics (on building and warehouse roofs), wind energy generators, and geothermal energy (cooling and heating). Hence, Goal 7 is achieved. Also, Goal 13 and Goal 3 are promoted; climate change is mitigated by having less GHGs, and good health is promoted for all by having fewer air pollutants resulting from the burning of fuel.

5.1.9 Climate actions

- *Greenhouse gas emission control and monitoring (indicators) (CO2, CH4, N2O) either from ports or shipping*: This measure clearly contributes to Goal 13, climate action, and Goal 3, good health of employees and surrounding society. Ports are better off addressing climate change mitigation; one way to do this is to establish GHG indicators and targets.
- *Climate change adaptation*: Through the adaptation of ports to climate change (Goal 13), various SDGs are enhanced. A healthy economy (Goal 8), healthy people, and sustainable cities are maintained (Goal 9 and Goal 11). Despite the expected sea level rise, trade continues, and port adaptation increases city resilience.

5.1.10 Innovation

- *Technological development, investment in research, and the use of electronic data interchange (EDI), single window, and port community systems with supply chain members:* These measures contribute to building resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation (Goal 9). Also, they contribute to promoting sustained, inclusive, and sustainable economic growth, with full and productive employment (Goal 8).

5.2. External collaboration sustainable measures and contribution to SDGs

In this section, we explain how port supply chain members (external collaboration) need to cooperate and maintain sustainable performance in general, and particularly when they interact with ports, thus promoting the SDGs.

5.2.1 Shipping lines / ocean carriers

- *Emission control and reduction:* Ships become compliant when they abide by international environmental regulations and use alternative cleaner fuel, e.g., LNG. They may complement their efforts by enrollment in environmental shipping indices, e.g., the environmental shipping index (ESI), the clean shipping index (CSI), green awards, etc. These measures could be adopted by ships, which contributes to Goal 13 (climate actions), because ships maintain less energy consumption, thus, fewer GHG emissions. Further, Goal 3 (good health) for employees and population is a byproduct of fewer pollutant emissions (e.g., NOx, SOx, PM).
- *Emission reduction technologies, such as scrubbers for SOx and PM, Selective Catalyst Redaction for NOx:* These measures from the shipping side contribute to Goal 3 (good health for population) and Goal 11 (sustainable cities), in which the adverse environmental effect per capita is reduced. Moreover, such measures promote sustainable industrialization that fosters innovation and upgrades technological capabilities (Goal 9).
- *In-port ship waste discharge:* This measure promotes and maintains a clean environment for life below water (Goal 14) and on land (Goal 15); that is, ships do not throw waste overboard which is instead collected at the port of call.
- *Ballast water treatment technology or in-port discharge*: This measure promotes Goal 14, which targets the life below water, by prevents ballast water that is full of invasive species and pollutions being discharged at sea or around port areas (unless it can be treated by port facilities) and, if discharged when ships are underway, it goes through particular onboard or outboard treatment.
- *Utilization of communication technologies, such as the use of electronic data interchange (EDI) and Sea Traffic Management (STM) (collaboration with ports). This applies to all of the supply chain members.* This measure contributes to Goal 8 (inclusive and sustainable economic growth and productive activities) by having a streamlined supply chain and better communications with ports and chains for efficient operations.

5.2.2 Trucking companies, freight forwarders, shipping agencies, customs agencies, inspection services, inland waterways, and railways

- *Safety and security of employees (while working within ports):* This measure promotes Goal 3 (good health) and Goal 8 (inclusive and sustainable economic growth). Also, Goal 11 (make cities and human settlements inclusive, safe, resilient, and sustainable) is promoted by maintaining the right level of safety and security for local employees.
- *Emission control mechanisms and reduction technologies (for trucks and vehicles):* This means fewer emissions in port and cities; hence, good health, sustainable cities, and climate actions are promoted (Goal 3, Goal 11, and Goal 13, respectively).
- *Efficiency improvement.* The turnaround time of trucks needs to be decreased, as do idling and traffic congestions in cities. Also, doing the work faster, with a minimum of employees and less energy consumption, improves efficiency. This measure achieves and promotes sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all (Goal 8). In addition, in some ways, they ensure sustainable consumption and production patterns (Goal 12). Further, the measure contributes to the achievement of Goal 13, climate actions, by having fewer fuel-burned fossil fuels; hence, fewer emissions.
- *Employee sustainability training*: This measure contributes to Goal 17, strengthening the means of implementation and revitalizing the global partnership for sustainable development.

5.2.3 Depots and dry ports

- *Multimodal transport facilities*: Dry ports build and accommodate railways and truck marshaling and handling yards, which promotes and streamlines transport to and from ports. This measure achieves sustainable economic growth, builds resilient infrastructure (Goal 8), promotes inclusive and sustainable industrialization and fosters innovation (Goal 9), and ensures sustainable consumption and production patterns (Goal 12).
- *Emission control mechanisms and sustainable infrastructure and superstructure*: Dry ports may follow port measures in controlling emissions and pursuing energy efficient building, e.g., LEED design for construction. By having such measures adopted, this means fewer emissions in cities; hence, Goal 3 (good health) and Goal 13 (climate actions) are promoted. Further, Goal 9 is promoted by having built resilient infrastructure.

5.2.4 Maritime administration

- *Monitoring of port safety and security:* maritime administrations have roles in policy making (Schröder-Hinrichs et al., 2020); thus, they monitor the compliance of operators and shipping in terms of ISPS code application or other alternatives**.** By this measure, Goal 9 (build resilient infrastructure) and Goal 11 (make cities and human settlements inclusive, safe, resilient, and sustainable) are promoted.
- *Safe, secure, sustainable navigation:* As regulators, administrations have the jurisdiction to maintain sustainable navigation such that ships and port crafts should comply with. This leads to less pollution and a better life for sea creatures (Goal 14), good health for seafarers (Goal 3), and good economic growth (Goal 9). Safety and security of transport and territorial seas leads to peace in societies (Goal 16) as illicit arm flows, corruption, and bribery are minimized.
- *Research and innovation:* Once maritime administrations foster research and innovation that is driven toward coast and port development, Goal 8 and Goal 9 are promoted, i.e., promoting sustained, inclusive, and sustainable economic growth, enhancing scientific research, and promoting inclusive and sustainable industrialization and fostering innovation.

5.2.5 Shippers

- *Use of sustainable shipping materials:* Shippers select shipping options that are less polluting, starting from packaging materials, shipping lines, and forwarders**.** This measure by

shippers promotes sustainability in cities (Goal 11), making cities and human settlements inclusive, safe, resilient, and sustainable. In addition, it promotes and ensures sustainable consumption and production patterns (Goal 12) and protects life on land by having less harmful materials invade the environment (Goal 15).

- *Sustainable import and export (Just in Time (JIT)):* By having goods arrive on time, based on information sharing and efficient supply chain coordination, inventory holding costs are decreased and very sustainable and efficient economic growth is promoted, i.e., promoting sustained, inclusive, and sustainable economic growth (Goal 8). Moreover, JIT decreases the waiting time of trucks at ports and reduces emissions, and this contributes to many goals, e.g., Goal-13 and Goal 3, climate actions and good health, respectively.

5.2.6 Communities and societies

- *Participate in port decision making and cooperation with port operators and port authorities:* Societies participate in decision making, such as port expansion plans. Communities could offer their points of view, what the impacts on them would be, and what ports could do to eliminate or reduce negative port impacts and externalities. This promotes and makes cities and human settlements inclusive, safe, resilient, and sustainable (Goal 11). Additionally, this measure promotes and strengthens the means of implementation and revitalizes the global partnership for sustainable development (Goal 17). Societal participation, indeed, strengthens the implementation of the goals, and is a sign of multi-relation for the implementation of sustainable development.

6. Discussions and conclusions

While this research attempted to build a framework of measures that work as enablers for port sustainable supply chain management, efforts were made to draw a connection between these kinds of measures across the UN SDGs. A framework of measures was built by factoring in port internal sustainable management, along with external collaboration measures, i.e., with members of supply chain management. The port internal sustainable management measures established in this research include shipping activities, transport activities, employees, economic generation, nature and environment protection, surrounding societies, security, renewable energy utilization and energy efficiency, climate actions, and innovation. On the other hand, external collaboration, which refers to the measures that supply chain members need to implement, includes various measures that span these members (customers, suppliers, and other stakeholders), i.e., shipping lines/ocean carriers, freight forwarders, shipping agencies, customs agents and inspection services, trucking companies, inland waterways, railways, depots and dry ports, maritime administrations, shippers, communities, and societies.

The significance of each measure, within the 3 dimensions of sustainability and how they contribute to the SDGs, were explained after being examined by the dashboard of 5Ps. Through the dashboard of 5Ps, it was feasible to shed light on the contributions of those measures to the achievement of the UN SDGs. The results of this research emphasized that port sustainable supply chain management measures contribute and promote all SDGs in general, directly or indirectly. Moreover, the key outcome of this framework is that it puts forward and clearly explains how port maritime authorities, public authorities, operators, and maritime supply chain members are expected to adopt the measures to improve various port sustainability practices and maintain sustainable performance. Ultimately, these measures contribute locally and internationally towards a more sustainable future, and particularly towards the SDGs. It is worth mentioning that the findings in this research are timely, due to scarcity in addressing port “sustainability” approaches (measures) with the “supply chain” and examination of port measure contribution to the UN SDGs. Results of this research open discussions on the academic side and inform practitioners (e.g., port managers, regulators etc.) on port sustainable supply chain measures including the contribution to UN SDGs.

Like any other research, several limitations exist. To begin with, the measures that were selected for the framework focus on the technical and operational aspects only. Thus, how such measures should be implemented from a "policies and regulation" perspective, as well as the applicability of these measures in ports, were not addressed. Obviously, these issues should be further examined by additional research efforts. On the other hand, the measures' contributions to the SDGs was based on the dashboard of 5Ps in addition to the authors' experience in port and shipping sustainability. While it could be argued that the method is not totally perfect in drawing a conclusion on each measure's contribution to the SDGs and in addition, such contribution reasoning is based on the authors' judgment, the study opens the way for further investigation for novel port roles in sustainable supply chain management and contribution to the UN SDGs; different views and backgrounds may result in different interpretations of measures and their contributions to the SDGs. Further research may examine the contribution of port measures to the SDGs by a focus group method, which may include supply chain, port, shipping, hinterland transport, and academic experts.

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