Sustainable Futures 2 (2020) 100019

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.elsevier.com/locate/sftr

# Developing a sustainability index for public health supply chains

Lakshmy Subramanian[a,*], Constantinos Alexiou[a], Joseph G. Nellis J[a], Pamela Steele[b], Foyeke Tolani[b]

[a] Cranfield University, College Road, Cranfield MK43 0AL, UK
[b] Pamela Steele Associate Ltd, Prama House, 267 Banbury Road, Oxford OX2 7HT, UK

ARTICLE INFO

*Keywords:*
Health supply chains
Approach of sustainability
Sustainability index
Health coverage

ABSTRACT

Researchers and practitioners alike have become increasingly aware and interested in the sustainability of supply chains. The majority of the research in this area includes the triple-bottom approach of sustainability understanding the economic, social, and environmental outcomes of supply chain functions. Several sustainability measures have been presented in the literature to recognize the sustainability of supply chains helping stakeholders in making strategic decisions. However, most of these studies analyse supply chains in developed nations and the research on sustainable supply chains in developing countries is scarce. The existing studies cover only the triple-bottom approach of sustainability in supply chains and there is a need to delve deeper into research to identify and quantify additional aspects of supply chain sustainability. Moreover, there is very little evidence of research on the sustainability of public health supply chains. Greater attempts in doing so will gain more comprehension of the emerging scope of sustainability practices in healthcare and help the various stakeholders improve their actions. Under this background, the main contribution of the paper is to devise a sustainability measure applicable to supply chains in public health. To this end, we develop a Supply Chain Sustainability Index which in addition to measuring the economic, social, and environmental footprints, also measures the stakeholder collaboration, health outcomes, and product/service and process quality initiatives. The index is comprised of a set of quantitative sub-indicators assessing multiple dimensions of sustainability across the supply chain participants concerning their role, location, capacity, etc. The sustainability index is modelled as a multi-dimensional vector and follows a hierarchal structure breaking down the different dimensions of sustainability to sets of sub-indicators and metrics. Although the current conceptual study does not provide any empirical evidence, it aims to propose this index to improve the evaluation and health coverage of public health supply chains. It will act as a foundation for further research and enable practical testing of the index in public health supply chains.

## 1. Introduction

Robust health supply chains are critical to any country and a well-functioning health system will require a supply chain to deliver and assure improved health outcome [21,36]. Although many envisage a supply chain as only procurement, warehousing, and distribution functions, integrated processed and collaboration is crucial to improve the accessibility of healthcare commodities. Supply chain management is a well-defined discipline, which has unfortunately not been used for strengthening health supply chains [23]. As a result, the public health supply chains (PHSC) in the low-and-middle-income countries (LMIC) remain weak endangering the health system's ability to respond to persistent health challenges [38,20]. Differences in economy, legislation, regulations, and standards pose difficulties in managing such supply chains which affect the overall performance especially in the developing countries [2]. Hence, the sustainability of supply chains is important to achieve in order to help countries overcome the bottlenecks of strained health systems and perform better.

The idea of sustainability came to the forefront only when people started understanding the impact of their own activities on the environment. People remained ignorant until the repercussions took the form of global warming, climate change, and other means of risks for human existence. The foremost discussion of this concept was done in the Burtland Report published by the United Nation in 1987. Different definitions of sustainability have emerged, which are more practice-oriented and delineates the characteristics of a sustainable society [31]. The definition of the European Union is considered to be more holistic covering many facets of sustainability including the economic, social and environmental effects of all policies that are examined systematically before deciding.

* Corresponding author.
*E-mail addresses:* lakshmy.subramanian@cranfield.ac.uk (L. Subramanian), constantinos.alexiou@cranfield.ac.uk (C. Alexiou), j.g.nellis@cranfield.ac.uk (J.G. Nellis J), pam@pamsteele.co.uk (P. Steele), foyeke.tolani@pamsteele.co.uk (F. Tolani).

https://doi.org/10.1016/j.sftr.2020.100019
Received 7 January 2020; Accepted 2 April 2020

The concept of sustainability should not be seen only in light of environmental degradation but has extended to accommodate the well-being of individuals, community, and the greater environment. To achieve sustainability targets coordination between the supply chain members is necessary [35]. The failure to establish collaboration across the different stakeholders will affect the overall competitiveness of the supply chain. Developing countries face an additional challenge as financial sustainability is considered more important and other aspects of it are completely neglected [19].

### *1.1. Sustainability in health supply chains*

There have been attempts to understand the impact of sustainability on healthcare. Attention has been diverted to focus on healthcare innovations and reducing the carbon footprints of healthcare activities [32,29]. Environmental sustainability in healthcare is understood in relation to waste management and pollution [5]. In addition to this, as healthcare organizations develop, the sustainability of customer care and employee care are becoming building blocks to quality healthcare and efficiency. This has necessitated the need for an integrated approach where these organizations can achieve better health outcomes [33]. In general, we found that the existing research on sustainability has mainly focused on environmental stability and organizational stability which concerns itself mainly on financial issues. Little efforts have been made to highlight the other areas of sustainability practices in healthcare

Similarly, there is very little evidence of research in the sustainability of public health supply chains, an area that very few studies have attempted to analyse. There are rare studies on isolated topics in healthcare logistics, like understanding outsourcing strategies of inventory management [27], the applicability of JIT (just-in-time) models in healthcare settings [3], etc. An objective model for assessing the environmental sustainability of healthcare organizations was developed in such a way that the results may be compared over time to create benchmarking tools [7]. Another effort recognised was qualitatively highlighting the driving forces for sustainability implementation in healthcare and propose strategies to continuously enhance the sustainability implementation in healthcare [24]. In general, the existing research on sustainability in supply chains of healthcare has mainly focused on environmental stability and organizational stability which concerns itself mainly on financial issues. Some studies have highlighted the social sustainability angle too. However, little efforts have been made to highlight the other areas of sustainability practices in health supply chains. Such an attempt will gain more understanding about the emerging scope of sustainability practices in healthcare and help the various stakeholders improve their actions.

### *1.2. Dimensions and measurement of sustainability*

Many researchers have tried to understand the various dimensions of sustainability at the industry, country, and global level. Past studies provide evidence of numerical models to highlight the link between supply chains and sustainability [10]. Green supply chains and the related strategic issues have been equally assessed [34]. Some authors believe that the definitions of supply chains are myopic to include the notion of sustainability and echo the challenges in measuring supply chain sustainability [39,15,18]. Most efforts towards evaluating supply chain sustainability have focused on environmental issues and use tools like life cycle assessment to measure supply chain sustainability [25,22,20,11]. The existing studies cover only the triple-bottom approach to sustainability which aims to see beyond the traditional bottom line of business to the profits that the business makes socially, environmentally, and economically. Additionally, most of the available evidence in this area analyse supply chains in developed nations and the research on sustainable supply chains in LMICs is scarce because of the challenge of coordination between developing and industrialized countries. In LMICs the dynamism and uncertainty of business environments and the lack of institutions prevent supply chains from learning, innovating and thus hinder the sustainability target achievement [37,2].

A number of sustainability measures have been presented to understand the sustainability of supply chains helping stakeholders in making strategic decisions. Optimization models are used to maximize sustainability as a linear benefit function of three components representing the economic, social and environmental dimensions of sustainability [6]. Other studies employed a multi-objective linear programming model to design and plan a closed loop supply chain [26]. An analytical model was proposed to assess the sustainability of the supply chain via a triad [8]. Whereas, a fuzzy inference system was applied to assess the sustainability of suppliers in the medical device industry regarding the three dimensions of sustainability [14]. Some studies utilised a probabilistic model for assessing the sustainability of the supply chain over time, while a sustainability measure which included dimensions of complex technical and economic efficiency was also established [1,4]. Some businesses try to use the balanced scorecard approach to evaluate the sustainable impact of economic, social and environmental activities supporting managers look beyond one measure of performance [12].

Under this background, the main contribution of this paper is to devise a sustainability measure applicable to supply chains in public health. Since a public health system is an ecosystem of various participants at different levels, sustainability will depend on the contribution of each participant and their role in improving the health outcomes of the supply chain. To this end, we have developed a Supply Chain Sustainability Index (SCSI) which is comprised of a set of quantitative sub-indicators assessing multiple dimensions of sustainability across the supply chain and not restricted to the triple-bottom down approach. The index like all the earlier attempts measures the economic, social, and environmental outcomes of supply chains. Furthermore, we have proposed to investigate the following key areas of supply chains in public health as well.

- The collaborative efforts of supply chains are included through a stakeholder outcome measure. Since the public health supply chains comprise of different participants, sustainability will depend on the contribution of each participant and their role in improving the health outcomes.
- Since the health supply chain carries the responsibility of improving health and saving lives, sustainability will also be influenced by health outcomes.
- Maintaining product/service quality and process quality is a key requirement for effective supply chains. Hence, supply chains also need to be gauged with respect to the various accreditations and certification required supporting in maintaining quality through the various functions.

Although the paper provides evidence from hypothetical health supply chains, the goal is to develop a measure which improves evaluations of supply chains and act as a tool of self-evaluation for improved health outcomes and coverage. It will act as the foundation for further research enabling practical testing of the index in public health supply chains.

## 2. Methodology

A measure that incorporates factors from more than one dimension, rather than a single dimension, gives a more complete picture of sustainability. However, it also raises a number of challenges with respect to measurement. The following steps have been identified for development of composite indicators [13].

i Develop a theoretical framework,
ii Identify and develop relevant variables
iii Standardize variables
iv Weight and group variables, and
v Perform sensitivity analysis

To create the new index, we have used the framework recommended by the Organisation for Economic Co-operation and Development in their handbook on Constructing Composite Indicators. This is one of the most authoritative guides for creating comparable measures and is widely used in literature. The main characteristic which needs to be addressed in the proposed measure is its capability to reflect the multi-dimensions of supply chains and to allow for differences between participants in the public health supply chain with respect to their role, location, capacity, etc. To this end, a sustainability index is proposed which is modelled as a multi-dimensional vector whose main components represent the economic, environmental, social, quality, stakeholder and health outcomes of the supply chain function. The index follows a hierarchal structure breaking down the different dimensions of sustainability to a set of sub-indicators and metrics. These were designed to be dimensionless and to extend over the range of (0, 1). This property allows the aggregation of all the indicators to a single index, SCSI.

Assuming that all of the relevant factors have been identified and the sub-indices are calculated, the next challenge is to either reduce or combine these to develop a single index. This process will involve some subjective aspects regarding the weights and the critical importance of each sub-index which can differ across the participants. To overcome this challenge a variety of techniques can be used as evidenced in the literature. Techniques used could be factor analysis and principal components analysis [17], Data Envelopment Analysis (DEA) [30], the Analytic Network Process (ANP), and the Analytic Hierarchy Process (AHP) [16].

The actions of the various supply chain participants will have direct and indirect impact on each other, the environment, and the society. The performance of each participant affects its own sustainability and does also shape the sustainability of the supply chain as a whole. The proposed index assesses each supply chain participant to understand its contribution to the overall supply chain sustainability. The framework adopted will be as follows;

- Assess the sustainability of each supply chain participant based on six dimensions of sustainability. For each entity the weighted sum of sub-indices of each of the six dimensions is calculated to give the economic Ei, environmental Eni, social Si, quality Qi, stakeholder Sti, and health Hi indicators, respectively. The weights will be assigned according to the activities performed, the goals, location and the prevailing business environment. A supply chain sustainability index (SCSI) for each participant is calculated using (I) and the same is repeated for all the entities of the supply chain.

$$\mathbf{SCSIp} = (\mathbf{w1} * \mathbf{Ei}) + (\mathbf{w2} * \mathbf{Si}) + (\mathbf{w3} * \mathbf{Eni}) + (\mathbf{w4} * \mathbf{Qi}) + (\mathbf{w5} * \mathbf{Sti}) + (\mathbf{w6} * \mathbf{Hi}) \quad \text{(I)}$$

where;

SCSIp = Supply Chain Sustainability Index for each participant

Ei =Economic outcome indicator, Si= Social outcome indicator, Eni=Environmental outcome indicator, Qi=Quality outcome indicator, Sti=Stakeholder outcome indicator, Hi=Health outcome indicator w1…w6 = Weights of the indicator (w1+w2+w3+w4+w5+w6=1)

- If there are more than one entity within the same group, then the sustainability index of the group (SCSIg)can be calculated by the geometric mean (GM) of individual sustainability index of all the entity within the group as seen in (II).

$$\mathbf{SCSIg} = \mathbf{m}\sqrt{\mathbf{SCSIi},\ \mathbf{SCSIii} \ldots .\mathbf{SCSIm}} \quad \text{(II)}$$

where 'm' is the number of entities within the group.

- The overall SCSI will be calculated by the GM of sustainability index of all the groups. The GM has been chosen to reflect the dependency of the sustainability of each group on the other. This encourages collaboration between different supply chain participants. For a supply chain with 'n' groups the overall sustainability (SCSI) will be calculated through (III).

$$\mathbf{SCSI} = \mathbf{n}\sqrt{\mathbf{SCSIgi},\ \mathbf{SCSIgii} \ldots .\mathbf{SCSIgn}} \quad \text{(III)}$$

The SCSI will take on values between zero and one, where one indicates the highest sustainability. The fact that the index value is dimensionless facilitates the comparison between different participants, roles and locations.

## 3. Description of the sub-indices

The proposed sustainability involves factors in six broad dimensions: environment, society, and economy, stakeholders, quality and health outcomes. Below we identify some variables that relate to each dimension.

### 3.1. Economic output

The economic dimension of the supply chain refers to the profits earned by the members of the chain as well as the economic benefits realized by the host nations, regions, and communities of those members. The economic dimension as shown in Table 1 is sorted into three categories. (1) *Monetary performance* refers to the ability of the firm to generate revenue and carry out its operations (2) *Financial health* refers to well-being and long-term viability of the firm with respect to financial resources. (3)*Efficiency* refers to the optimum allocation and utilisation of resources to serve the stakeholder by reducing waste and inefficiency.

### 3.2. Social output

The social dimension of sustainability relates to the human capital of the supply chain. Improving sustainability with respect to the social dimension involves developing and maintaining business practices that are fair and favourable to the workforce, communities, and regions touched by the supply chain. This can be categorised into two broad categories. (1) *Workplace* refers to the internal human resources, i.e., those who work within the supply chain and factors contributing to their empowerment and well-being. (2) *Community* refers to all people outside of the supply chain, including those who are directly and indirectly affected by the chain's performance. The various sub-indicators are shown in Table 2.

### 3.3. Environmental output

Improving environmental sustainability means reducing the ecological footprint of the supply chain. Of the three dimensions, the environmental aspect of supply chain management has been studied the most [16]. This is divided into the following categories as seen in Table 3. (1) *Sources* refer to the emissions caused by local impacts and the use of energy in the supply chain functions. (2) *Disposal* refers to the recycling and waste diversion efforts across the supply chain functions.

### 3.4. Quality outcome

This refers to the internal and external systems, procedures, and values that relate to the various dimensions of supply chains. These accreditations and reporting arrangements will aid in attaining better conformance and compliance with technical specification, legislative requirements, etc. which will provide assurance to customers and the various other stakeholders. We divide this into two categories as seen in Table 4. (1) *Accreditations* signal that the product/service follows the required specifications and will fulfil the demand of the various stakeholders. Examples will include ISO 14,000, ISO 9000, energy standards, etc. (2) *Reporting* will induce better accountability in supply chain functions and will force the various stakeholders to overcome non-conformances. Examples will include Environmental management systems, EPA, OSHA, CPCS.

**Table 1**
Economic outcome indicators.

| Category | Metric | Measurement | | | |
|---|---|---|---|---|---|
| Monetary | Productivity | Output/input | Economic sustainability of supply chain functions | **Economic outcome sub index (Ei)** | Ei will be a GM of the 6 economic metrics |
| | Order measurement | Successful orders/Total orders | | | |
| Financial health | Profitability | Revenue/Cost | | | |
| | Value added | Profit/selling price | | | |
| Efficiency | Days of supply | Average inventory/Average monthly demand | | | |
| | Product/Service delivery | Actual delivery/Total production-procurement | | | |

**Table 2**
Social outcome indicators.

| Category | Metric | Measurement | | | |
|---|---|---|---|---|---|
| Workplace (Internal) | Wage Ratio | Top wages/Bottom wages | Human capital or social sustainability of supply chain functions | **Social outcome sub index (Si)** | Si will be the GM of all the 6-social metric |
| | Health Delivery | Health expenditure per capita/Total expenditure | | | |
| | Gender Equality | Female personnel/Male personnel | | | |
| | Capacity Development | Training or development budget/Total expenditure | | | |
| Community (External) | Product recalls | Total notifications/total sales | | | |
| | Employment opportunities | Total jobs offered/Unemployment | | | |

**Table 3**
Environmental outcome indicators.

| Category | Metric | Measurement | | | |
|---|---|---|---|---|---|
| Sources | Emissions | Emissions per unit/total units | Environmental sustainability of supply chain functions | **Environmental outcome sub index (ENi)** | ENi will be the GM of all the 4-social metric |
| | Energy | Renewable energy/Total energy used | | | |
| Disposal | Recycling | Recyclable weight this month/Recyclable weight last month | | | |
| | Waste Diversion | Waste diverted/Total amount waste | | | |

**Table 4**
Quality outcomes indicators.

| Category | Metric | Measurement | | | |
|---|---|---|---|---|---|
| Accreditations | Accreditations (products/services) | Existing certifications/Mandatory Certifications | Quality sustainability of supply chain functions | **Quality outcome sub index (Qi)** | Qi will be the GM of the 2-quality metrics |
| Reporting | Reporting (processes) | Existing reporting/Mandatory reporting | | | |

### *3.5. Stakeholder outcomes*

Since the supply chain is an ecosystem of different stakeholder, sustainability will depend on their actions and outcomes. Hence understanding the supply chain in relation to the various interactions of the stakeholders will provide a clear vision of the market and level of services required. This is broadly divided into the following categories. (1) *Market structure* refers to the health of the market and the configuration of the supply chain participants. (2) *Collaboration* refers to the practices aimed at improving the level of satisfaction and achieving better satisfaction (Table 5).

### *3.6. Health outcomes*

The sustainability of a public health supply chain will be gauged the health and well-being of the patients. Every supply chain partner contributed to the various activities to improve the health outcome and save lives. Positive supply chain interventions will result in expedited service delivery, access to medicines, improved affordability and efficacy of medicines. The indicators can be seen in Table 6.

The various sub-indicators contribute to developing the SCSI. The composite index is a weighted average of the six dimensions and can be calculated for each participant of the supply chain. If there is more than one participant in a group, the individual indices are aggregated to calculate the supply chain index of the group. The various group indices are aggregated to develop the composite index for the entire supply chain as shown in Fig. 1.

## 4. Empirical investigations

In this section a hypothetical example is used to illustrate the working of the sustainability index. This example can be applied to health supply chains of all countries-both developed nations and LMIC. The assessment framework is of critical importance to a nation since it acts as an indicator of the health system and its overall impact on the well-being of people. For our empirical analysis we follow the network as depicted

**Table 5**
Stakeholder outcome indicator.

| Category | Metric | Measurement | | | |
|---|---|---|---|---|---|
| Market Structure | Depth of suppliers | Existing suppliers/Total number of suppliers in the market | Stakeholder outcome of supply chain functions | **Stakeholder outcome sub index (STi)** | STi will be the GM of all the 4-social metric |
| | Breadth of customers | Existing customers/Total customers in the market | | | |
| Collaboration | Accuracy of feedback | Non-conformance rectified/Non-conformance reported | | | |
| | Level of satisfaction | Repeat interactions or delivery/Total interactions or delivery | | | |

**Table 6**
Health outcomes indicators.

| Category | Metric | Measurement | | | |
|---|---|---|---|---|---|
| Healthcare and well-being | Service delivery | Patients served/Total patients | Health outcome sustainability of supply chain functions | **Health outcome sub index (Hi)** | Hi will be the GM of all the 4-social metric |
| | Efficacy of healthcare | Counterfeits identified/Total consumption | | | |
| | Accessibility | Rural health points/Total health points | | | |
| | Affordability | State sponsored healthcare expenditure/Total health expenditure | | | |

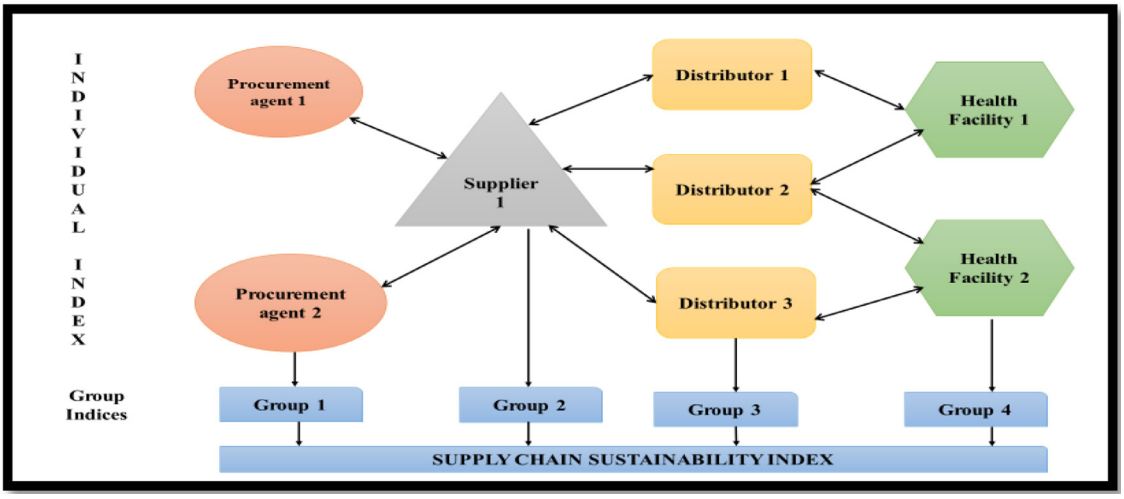


**Fig. 1.** Structure of the SCSI.

in Fig. 1. It consists of four echelon with a total of eight participants: two procurement agents, one supplier, three distributors, and two health facilities. The hypothetical values of the various sub-indicators (as discussed in the earlier sections) for each participant with the corresponding weights are shown in Table 7.

The weighted sum of the indicators results in the economic, social, environmental, quality, stakeholder and health dimensions. The SCSIp, SCSIg, and overall SCSI calculated using the formulae explained in the earlier section are detailed in Table 8.

## 5. Findings and discussions

The empirical investigation helps us to understand the following areas of sustainability in health supply chains;

- The performance of each participant in the supply chain can be analysed with respect to their sustainability index. This will facilitate in identifying participants with critical sustainability levels.
- The level of sustainability at each echelon recognizes the performance of each group of participants in the supply chain vis-a-vis the others.
- The analysis can yield comparisons of the various indicators and sub-indicators. Since all the values are normalized, a comparison of the different indicators across the supply chain participants is possible.
- We identify sets of indicators and sub-indicators which have the highest and lowest levels of sustainability. This will aid the different participants to compare and contrast their individual performances. Good practices can also be distinguished and the knowledge of the same can be embedded across the different supply chain functions. Based on the weights assigned to the contribution of each indicator towards sustainability, priority can be given to specific indicators to improve the participant's sustainability.
- The sustainability assessment of each dimension will reflect which sub-indicators are given priority and which aspects are being ignored within health supply chains.
- The recognition of the different dimensions may help in identifying strategies to improve individual participants as well as overall supply chain sustainability.

**Table 7**
Sub-indicators of a hypothetical health supply chain.

| Supply chain participants | Weight | Economic (Ei) | Weight | Social (Si) | Weight | Environmental (Eni) | Weight | Quality (Qi) | Weight | Stakeholder (Sti) | Weight | Health (Hi) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Procurement Agent 1 | 0.05 | 0.56 | 0.3 | 0.76 | 0.023 | 0.45 | 0.06 | 0.76 | 0.2 | 0.87 | 0.4 | 0.34 |
| Procurement Agent 2 | 0.4 | 0.78 | 0.6 | 0.56 | 0.31 | 0.34 | 0.03 | 0.56 | 0.12 | 0.12 | 0.27 | 0.43 |
| Supplier 1 | 0.3 | 0.56 | 0.05 | 0.76 | 0.08 | 0.25 | 0.1 | 0.57 | 0.4 | 0.37 | 0.6 | 0.31 |
| Distributor 1 | 0.3 | 0.45 | 0.09 | 0.36 | 0.34 | 0.89 | 0.1 | 0.67 | 0.05 | 0.61 | 0.3 | 0.59 |
| Distributor 2 | 0.6 | 0.12 | 0.03 | 0.57 | 0.47 | 0.59 | 0.08 | 0.32 | 0.4 | 0.27 | 0.07 | 0.68 |
| Distributor 3 | 0.07 | 0.4 | 0.5 | 0.9 | 0.57 | 0.06 | 0.04 | 0.45 | 0.6 | 0.39 | 0.12 | 0.6 |
| Health Facility 1 | 0.56 | 0.12 | 0.12 | 0.27 | 0.43 | 0.3 | 0.45 | 0.09 | 0.36 | 0.34 | 0.89 | 0.1 |
| Health Facility 2 | 0.31 | 0.34 | 0.03 | 0.56 | 0.12 | 0.12 | 0.27 | 0.07 | 0.4 | 0.5 | 0.9 | 0.57 |

**Table 8**
SCSI of the health supply chain.

| Supply chain participants | SCSIp | SCSIg | SCSI |
|---|---|---|---|
| Procurement Agent 1 | 0.622 | 0.38236 | **0.571** |
| Procurement Agent 2 | 0.9007 | | |
| Supplier 1 | 0.617 | 0.617 | |
| Distributor 1 | 0.7445 | 0.69857 | |
| Distributor 2 | 0.5476 | | |
| Distributor 3 | 0.8362 | | |
| Health Facility 1 | 0.4805 | 0.646 | |
| Health Facility 2 | 0.8685 | | |

## 6. Conclusion

The study is a novel attempt to emphasize the importance and quantify the sustainability of PHSC. The proposed index purports to raise awareness as well as provide an enhanced measure for health outcomes and well-being. We envisage that the index will benefit stakeholders to understand the impact of their actions and pave way for a stronger health system. However, the study does have a certain limitation.

- The different sub-indicators do not present an exhaustive list of the various dimensions of sustainability. Some of the measures might overlap in certain situations and interactions. The primary challenge while evaluating a sustainability measure is not the lack of inputs, but to decide what to do with many inputs available [9].
- The process of assigning weights can also result in certain subjectivity. Although we have identified some popular methods used to assign weights in the literature, the appropriate method must be chosen based on the industry requirements and constraints.
- Data collection can be a major limitation as not all factors that are considered important for sustainability might be believed to be relevant by the different stakeholders [28].
- The sustainability of supply chains will be affected by additional factors in the future which will need to be addressed. Subject to data availability, the proposed conceptual framework and approach can be used by future researchers to identify new variables and create an extended version of the same index. This can be achieved as the fundamental structure of measurement remains unchanged.

Despite these challenges, the proposed index will help in expanding one's thinking about the sustainability of supply chains in public health. It is difficult to have a perfect sustainability measure. However, the current index can act as a tool of self-evaluation for improved health outcomes and coverage. It will act as the foundation for further research enabling practical testing of the index in public health supply chains.

## Declaration of Competing Interest

None.

## References

[1] P. Ahi, C. Searcy, Assessing sustainability in the supply chain: a triple bottom line approach, Appl. Math. Model. 39 (2014) 2882–2896 https://doi.org/10.1016/j.apm.2014.10.055.
[2] M. Akamp, M. Müller, Supplier management in developing countries, J. Clean Prod. 56 (2013) 54–62 https://doi.org/10.1016/j.jclepro.2011.11.069.
[3] R. Balakrishnan, T. Linsmeier, M. Venkatachalam, Financial benefits of JIT adoption: effects of customer concentration and cost structure, Account. Rev. 71 (2) (1996) 183–206.
[4] G. Barbiroli, New indicators for measuring the manifold aspects of technical and economic efficiency of production processes and technologies, Technovation 16 (7) (1996) 341–356 https://doi.org/10.1016/0166-4972(96)00024-7.
[5] D.M. Berwick, A.D. Hackbarth, Eliminating waste in US health care, JAMA 307 (14) (2012) 1513–1516 https://doi.org/10.1001/jama.2012.362.
[6] R. Bhinge, R. Moser, E. Moser, G. Lanza, D. Dornfeld, Sustainability optimization for global supply chain decision-making, Procedia CIRP 26 (2015) 323–328 https://doi.org/10.1016/j.procir.2014.07.105.
[7] María Carmen Carnero, Assessment of Environmental Sustainability in Health Care Organizations, Sustainability 2015 7 (2015) 8270–8291 https://doi.org/10.3390/su7078270.

[8] E. Chardine-Baumann, Valerie Botta-Genoulaz, A framework for sustainable performance assessment of supply chain management practices, in: 41st International Conference on Computational Industrial Engineering 2011, 76, 2011, pp. 56–61. https://doi.org/10.1016/j.cie.2014.07.029.
[9] J. Custance, H. Hillier, Statistical issues in developing indicators of sustainable development, J. R. Stat. Soc. 161 (1998) 281–290 https://doi.org/10.1111/1467-985X.00108.
[10] M.P. de Brito, R. Dekker, S.D.P. Flapper, Reverse logistics: a review of case studies, in: B. Fleischmann, A. Klose (Eds.), Distribution Logistics. Lecture Notes in Economics and Mathematical Systems, 544, Springer, Berlin, Heidelberg, 2005 https://doi.org/10.1007/978-3-642-17020-1_13.
[11] E.P.A. (U.S. Environmental Protection Agency), Life Cycle Assessment: PPrinciples and Practice, National Risk Management Laboratory, 2006 Technical Report EPA/600/R-06/060.
[12] M.J. Epstein, M.-.J. Roy, Making the business case for sustainability: linking social and environmental actions to financial performance, J. Corporate Citiz. 9 (2003) 79–96.
[13] M. Freudenberg, Composite indicators of country performance: a critical assessment, Organisation for Economic Co-Operation and Development Technical Report STI 2003/16, OECD Directorate for Science, Technology, and Industry, Paris, France, 2003.
[14] P. Ghadimi, C Heavy, Sustainable supplier selection in medical device industry: toward sustainable manufacturing, Procedia CIRP 15 (2014) 165–170 https://doi.org/10.1016/j.procir.2014.06.096.
[15] A. Gunasekaran, C. Patel, R. Mcgaughey, A framework for supply chain performance measurement, Int. J. Prod. Econ. 87 (3) (2004) 333–347 https://doi.org/10.1016/j.ijpe.2003.08.003.
[16] R. Handfield, S. Walton, R. Sroufe, S. Melnyk, Applying environmental criteria to supplier assessment: a study in the application of the Analytical Hierarchy Process, Eur. J. Oper. Res. 141 (1) (2002) 70–87 Volume-https://doi.org/10.1016/S0377-2217(01)00261-2.
[17] W. Härdle, L. Simar, Applied Multivariate Statistical Analysis, second ed., Springer-Verlag, Berlin, 2007.
[18] A.A. Hervani, M.M. Helms, J. Sarkis, Performance measurement for green supply chain management, Benchmarking 12 (4) (2005) 330–353 https://doi.org/10.1108/14635770510609015.
[19] M.J. Hutchins, J.W Sutherland, An exploration of measures of social sustainability and their application to supply chain decisions, J. Clean Produ. 16 (2008) 1688–1698 https://doi.org/10.1016/j.jclepro.2008.06.001.
[20] M.M. Khasreen, P. Banfill, G. Menzies, Sustainability 1 (2009) 674–701 https://doi:10.3390/su1030674.
[21] S. Kraiselburd, P. Yadav, Supply chains and global health: an imperative for bringing operations management scholarship into action, Prod. Oper. Manag. 22 (2) (2013) 377–381 https://doi.org/10.1111/j.1937-956.2011.01315.x.
[22] A.J.D. Lambert, Life-cycle chain analysis, including recycling, in: J. Sarkis (Ed.), Greener Manufacturing and Operations: From Design to Delivery and Back, Greenleaf Publishers, Sheffield, UK, 2001, pp. 36–55.
[23] P. Larson, A. Halldorsson, What is SCM? and, where is it? J. Supply Chain Manag. 38 (3) (2002) 36–44 https://doi.org/10.1111/j.1745-493X.2002.tb00141.x.
[24] M. Marimuthua, H. Pauloseb, Emergence of sustainability based approaches in healthcare: expanding research and practice, Procedia - Soc. Behav. Sci. 224 (2016) (2016) 554–561..
[25] K. McIntyre, H. Smith, A. Henham, J. Pretlove, Environmental performance indicators for integrated supply chains: the case of Xerox Ltd., Supply Chain Manag. 3 (3) (1998) 149–156 https://doi.org/10.1108/13598549810230877.
[26] B. Mota, M. Gomes, A. Carvalho, A. Barbosa-Povoa, Towards supply chain sustainability: economic, environmental and social design and planning, J. Clean Prod. (2014) http://dx.doi.org/10.1016/j.jclepro.2014.07.052.
[27] L. Nicholson, A. Vakharia, S.S. Erenguc, Outsourcing inventory management decisions in healthcare: models and application, Eur. J. Oper. Res. 154 (1) (2004) 271–290 http://doi.org/10.1016/S0377-2217(02)00700-2.
[28] M. Nagel, Environmental quality in the supply chain of an original equipment manufacturer: what does it mean? in: J. Sarkis (Ed.), Greening the Supply Chain, Ed., Springer, Berlin, 2006, pp. 325–340.
[29] R. Price, O. Sergelen, C. Unursaikhan, Improving surgical care in Mongolia: a model for sustainable development, World J. Surg. 37 (2013) 1492–1499 http://doi.org/10.1007/s00268-012-1763-1.
[30] G. Reiner, P. Hofmann, Efficiency analysis of supply chain processes, Int. J. Prod. Res. 44 (23) (2006) 5065–5087 Volume:https://doi.org/10.1080/00207540500515123.
[31] K.-.H. Robèrt, B. Schmidt-Bleek, J. Aloisi de Larderel, G. Basile, J.L. Jansen, R. Kuehr, P.R. Thomas, M. Suzuki, P. Hawken, M. Wackernagel, Strategic Sustainable Development: selection, Design and Synergies of Applied Tools, J. Clean Prod. 10 (2002) 197–214.
[32] Z.R. Rosenberg-Yunger, A.S. Daar, P.A. Singer, D.K. Martin, Healthcare sustainability and the challenges of innovation to biopharmaceuticals in Canada, Health Policy 87 (2008) 359–368 https://doi.org/10.1016/j.healthpol.2008.02.004.
[33] S.G. Saad, Integrated environmental management for hospitals, Indoor Built Environ. 12 (1–2) (2003) 93–98 https://doi.org/10.1177/1420326X03012001015.
[34] J. Sarkis, A strategic decision framework for green supply chain management, J. Clean Prod. 11 (4) (2003) 397–409 https://doi.org/10.1016/S0959-6526(02)00062-8.
[35] Andreas Seiter, A practical approach to pharmaceutical policy (English), Directions in development; Human Development, World Bank, Washington, DC, 2010.
[36] S. Seuring, M. Muller, From a literature review to a conceptual framework for sustainable supply chain management, J. Clean Prod. 16 (2008) (2008) 1699–1710 https://doi.org/10.1016/j.jclepro.2008.04.020.
[37] B.S. Silvestre, Sustainable supply chain management in emerging economies: environmental turbulence, institutional voids and sustainability trajectories, Int. J. Prod. Econ. 167 (2015) 156–169 https://doi.org/10.1016/j.ijpe.2015.05.025.
[38] O. Sued, C. Schreiber, N. Girón, M. Ghidinelli, HIV drug and supply stock-outs in Latin America, Lancet Infect. Dis. 11 (11) (2011) 810–811 https://doi.org/10.1016/S1473-3099(11)70301-2.
[39] G. Svensson, Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example, Supply Chain Manag. 12 (4) (2007) 262–266 https://doi.org/10.1108/13598540710759781.