Developing a framework for evaluating sustainability index for logistics service providers: graph theory matrix approach

Anchal Gupta
Delhi Technological University, Delhi, India, and
Rajesh Kumar Singh
Department of Operations Management, Management Development Institute, Gurgaon, India

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Abstract

Purpose – The purpose of this study is to identify sustainability practices and to propose a framework for evaluating the sustainability index of logistics service providers (LSPs).

Design/methodology/approach – Sustainable practices followed by LSPs are identified through literature review and analysis of a case study. Thirteen such sustainable practices are identified. Thereafter, with expert inputs, nine sustainable practices are shortlisted and considered for the evaluation of the sustainability index in the proposed framework. Graph Theory Matrix Approach has been applied to evaluate the sustainability index of an LSP.

Findings – Major practices identified for evaluating sustainability index include the use of recyclable packaging, use of renewable energy sources, green procurement, reduction in carbon emissions, use of CNG/electric vehicles, rainwater harvesting and so on. The sustainability index of an LSP is evaluated by using the proposed framework.

Practical implications – LSPs can benchmark their sustainability index with respect to the best in the industry. Based on it, LSPs can also identify potential areas for improvement.

Originality/value – Novelty of the study lies in the proposed framework for evaluation of sustainability index which can be used to develop strategies for green logistics. LSPs can also improve their performance in terms of sustainability measures by adopting green logistics.

Keywords Logistics service providers, Sustainable practices, Sustainability index, Graph theory matrix approach, case study

Paper type Research paper

1. Introduction

"Sustainability" – a term first coined by the World Commission on Environment and Development (WCED) in the year 1987 (WCED, 1987) – was adopted gradually by most of the organizations around the world. In the year 2015, the United Nations has set up 17 sustainable development goals (SDGs) for improving sustainable development in business organizations as well as world economies, with a target to achieve these goals by 2030 (Szabo *et al.*, 2016; Salvia *et al.*, 2019; Modgil *et al.*, 2020). Due to this, organizations worldwide are seeking to implement sustainable solutions. With the increasing scarcity of resources as well as increasing needs of society and organizations, there is an urgent need to ensure sufficient availability for current use and conserve for meeting the needs of future generations. Moreover, the environment is continuously deteriorating (Seidel *et al.*, 2013). Therefore, many organizations including logistics service providers (LSPs) are adopting and implementing sustainable practices for optimum use of scarce resources and taking steps for a better global future.

Compared to other industry segments, LSPs contribute more toward environmental degradation in terms of noise and air pollution, carbon emissions, fuel consumption, global warming, resource depletion, and so on (Jazairy and Haartman, 2018). The logistics sector is

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expected to grow exponentially, which will lead to even worse environmental conditions (Wang *et al.*, 2016). Therefore, LSPs are required to initiate sustainable logistics solutions for handling current and upcoming environmental challenges. Previous studies have explored the benefits of the adoption of green practices by various organizations (Perotti *et al.*, 2012; Dubey *et al.*, 2017; Majumdar and Sinha, 2018). Many authors have also discussed the impact of the implementation of sustainable practices on firms' performance (Perotti *et al.*, 2012; Green *et al.*, 2019). Ansari and Kant (2017) explored the positive impact of the sustainable practices of logistics service providers on their efficiency, productivity, and profitability. Many authors have also highlighted the importance of the triple bottom line approach in logistics for improving sustainability (Agrawal *et al.*, 2016; Agrawal and Singh, 2019; Halldorsson, 2019; Kumar and Goswami, 2019).

The existing literature focuses more on green logistics practices in developed countries compared to developing countries (Gandhi *et al.*, 2015; Mangla *et al.*, 2015; Agrawal and Singh, 2019). Gupta and Singh (2020) indicate the need for greater emphasis on developing countries to create a balance between environmental sustainability and the operational excellence of LSPs. Presently, due to environmental consciousness, even consumers in developing nations have started expecting green products. LSPs in developing economies have initiated sustainable practices but only on a small scale. In India, LSPs have started transforming their processes into green processes by changing their conventional fleet into CNG (Compressed Natural Gas) or hybrid fleets for reducing carbon emissions. LSPs have also initiated various activities such as planting trees in the surroundings of their facilities, storing rainwater for washing vehicles and installing solar panels for saving electricity (Gupta *et al.*, 2018). LSPs are also working toward a reduction in waste, which is created in different forms such as underutilized resources, replication of tasks, and inadequate planning of resource allocation (Qian *et al.*, 2019). Moreover, LSPs are exploring alternative ways of reducing carbon emissions, fuel consumption, and noise levels for long-term sustainability. Despite the measures being adopted by LSPs, the actual adoption rate is very low due to lack of continuous evaluation measures. Owing to the lack of appropriate frameworks in the literature, most LSPs struggle in evaluating their sustainability index (Chhabra and Singh, 2016). There is, therefore, a need to perform an in-depth analysis of sustainable practices followed by LSPs and to evaluate the sustainability index of such providers in a developing country. This study analyzes and evaluates the sustainability performance of LSPs in the Indian context. The main objectives of this study are as follows:

(1) To identify the sustainable practices followed by LSPs

(2) To analyze the sustainable practices specifically for LSPs in the Indian context

(3) To evaluate the sustainability index using a Graph Theory Matrix Approach (GTMA)

(4) To propose a framework for evaluating the sustainability index of LSPs

This study is further elaborated under the following sections. Section 2 comprises the literature review on green initiatives and sustainable practices followed by LSPs. In Section 3, the case study method is used to identify and analyze sustainable practices in developing economies. In Section 4, the sustainability index has been evaluated by using GTMA. The implications of the study along with future scope are discussed in Section 5. The conclusions of the study are concluded in Section 6.

2. Literature review

There is a significant body of literature available on evolution, adoption, and implementation of sustainable practices in both the manufacturing and service sectors (Perotti *et al.*, 2012;

Anwer *et al.*, 2018; Majumdar and Sinha, 2018; Mensah and Casadevall, 2019). Sustainability means the conservation of natural resources and judicious use of resources for long term business continuity. Due to continuous environmental degradation and scarcity of resources, resource sustainability has become an important concern for all organizations including LSPs (Coaffee, 2008; Zhang *et al.*, 2017). LSPs have started redefining their conventional processes into green processes as a contribution towards society and the environment (Ferreira *et al.*, 2015). Previous studies discussed the adoption and importance of sustainability in the field of logistics (Gandhi *et al.*, 2015; Mangla *et al.*, 2017). Centobelli *et al.* (2017) conducted a systematic literature review on green and sustainable practices followed by LSPs by exploring more than 415 articles from 1960 to 2014. Evangelista *et al.* (2018) conducted a comprehensive literature review on the environmental sustainability of LSPs for the period of 2000–2016.

Researchers have not only conducted comprehensive literature reviews on environmental sustainability but also discussed the benefits that organizations can obtain by implementing sustainable practices. Various authors captured different aspects of logistics and linked them with sustainability measures. For example, Wilding *et al.* (2012) highlighted the importance of supplier assessment and collaboration in improving sustainability. Martinez-Jurado *et al.* (2014) explored the relationship between lean management, supply chain management, and sustainability. Marques (2019) conducted a detailed and systematic literature review on sustainable supply network management from a knowledge perspective. Many practitioners have already proved the strong relationship among the implementation of sustainable practices, an increase in profitability, and improvement in organizational performance (Perotti *et al.*, 2012; Singh *et al.*, 2016; Ansari and Kant, 2017). Several researchers have established the relationship among implementation of green sustainable practices and organizational culture, service quality, and operational performance (Zhu *et al.*, 2008; Bask *et al.*, 2018; Garcia-Dastugue; Eroglu, 2019; Green, 2019; San-Ong *et al.*, 2019).

Despite the extensive literature on logistics and sustainability, LSPs, specifically those in developing countries, are yet to implement green practices in all their processes (Agrawal and Singh, 2019). As a result, it is imperative for LSPs in emerging economies to practice resource conservation and ensure long-term business continuity (Singh and Agrawal, 2018). Moreover, organizations, including LSPs, are expected to follow strict guidelines for environmental protection, issued by the government and the United Nations (UN). The UN has set sustainable development goals (SDGs-7, 12 and 13) for the implementation of sustainable practices in the organizations (The Sustainable Development Goals Report, 2019). The UN has also emphasized the development of metrics and indicators for measuring sustainable development at the environmental, social, and economic levels. On the other end, consumers are also becoming proactive and demanding eco-friendly products (Green *et al.*, 2015). These requirements by the government, the UN, and customers are building pressure on LSPs.

Many authors have discussed the hurdles in the adoption of sustainable practices and highlighted methods for measuring the performance of sustainable supply chains (Taticchi *et al.*, 2013; Baird, 2017; Thanki; Thakkar, 2018). Pazirandeh and Jafari (2013) critically evaluated the impact of sustainability strategies on logistics efficiency using structural equation modeling (SEM). Tajbakhsh and Hassini (2015) proposed a performance measurement framework for measuring the sustainability of various industries based on seven sustainability dimensions (economic, environmental, social, reputable, valuable, equitable, and sustainable). Trianni *et al.* (2019) analyzed 26 small and medium manufacturing organizations of Germany and Italy and observed that the organizations accorded more importance to economic indicators over environmental and social indicators. They developed a novel framework for measuring sustainability indicators. Gardas *et al.* (2019) analyzed sustainable supply chain determinants for measuring the business performance of the oil and gas supply chain. Chowdhury and Paul (2020) reviewed the

applications of multi-criteria decision-making methods (MCDM) for measuring performance, including enablers of, and barriers to, corporate sustainability.

Most LSPs struggle in evaluating their sustainability index due to the lack of appropriate frameworks (Chhabra and Singh, 2016). It is crucial to measure the performance of LSPs in terms of their sustainability. This study proposes a framework for measuring the sustainability index of LSPs. This will help other LSPs understand their current position and take corrective measures if required. This provides a significant opportunity to conduct an in-depth analysis of the sustainable practices followed by LSPs in developing countries and to evaluate their sustainability index to understand the current situation of LSPs in the Indian market. Therefore, the following research questions have been developed:

RQ1. What are the sustainable practices followed by LSPs in developing countries to fulfill the UN's sustainable development goals?

RQ2. How can the sustainability of Indian LSPs be measured?

RQ3. What suggestions can be made to other LSPs for better achievement of SDG goals?

The sustainable practices followed by LSPs are identified through a literature review as discussed in the next section and a case study is also conducted on Indian LSP to understand their sustainable practices closely as discussed in Section 3.

2.1 Identification of sustainable practices from literature review

Previous studies have explored sustainable practices adopted by LSPs specifically in context to developing countries. It has been observed that LSPs have emphasized on the reduction of carbon emissions and fuel consumption as an initiative towards the environmental protection (Yao *et al.*, 2015; Aldakhil *et al.*, 2018; Liu *et al.*, 2018). Agrawal *et al.* (2016) have explored the importance of reverse logistics to assist return management and to make optimum use of resources. Renewable resources like solar and hydro products are more preferred nowadays over expensive single time use products for long term sustainability of products (Dubey *et al.*, 2017; Sureeyatanapas *et al.*, 2018). Reuse and recycling of packaging material and pallets are also done through plastic totes and heavy containers in order to save resources (Boubeta *et al.*, 2018). The adoption of green practices in the logistics sector has also become evident by converting manual processes (paper-work) into e-processes (paper-less) through digitalization (Kayikci, 2018). The following sustainable practices are identified through the literature review:

(1) *Use of reusable or recyclable packaging:* To promote green practices, several LSPs have started using plastic totes and heavy-duty containers which are cost-efficient and can be used for multiple trips (Centobelli *et al.*, 2018; Regattieri *et al.*, 2019). Paper, cardboard, corn starch, and bubble wrap, etc. are biodegradable and preferred for packaging (Gupta *et al.*, 2020). In India, Transport Corporation of India (TCI) and Agarwal Packers and Movers Ltd. are actively reusing and recycling packaging materials for making cost-effective and sustainable logistics system (Bhushan and Malviya, 2018)

(2) *Use of renewable energy sources:* The best way to conserve limited resources is to maximize the use of renewable energy sources. LSPs have initiated the use of solar energy and hydropower for many logistical activities instead of single-time use electric ones. Installation of solar panels for producing electricity (Fontes, and Freires, 2018; Gupta *et al.*, 2018), transparent roofs for natural light to enter during daytime (Tascioglu and Keser, 2019) and storage of rainwater for gardening and cleaning vehicles (Piecyk and Björklund, 2015; Gupta *et al.*, 2018) indicate the prominent use of natural resources by LSPs. All Cargo Logistics sets a wonderful example by providing renewable energy transportation from end to end logistics (Choudhary, 2019).

(3) *Green procurement:* Green procurement is the foremost step towards green logistics (Teixeira *et al.*, 2018). LSPs prefer to purchase products or services, which will cause a minimum adverse effect on the environment. The use of alternative fuel, proper planning for unutilized material, waste reduction, and use of recyclable and reusable products can support green procurement initiatives (Meehan and Bryde, 2011; Centobelli *et al.*, 2018). DHL has adopted green logistics to make our planet more sustainable by reducing emissions and moving towards the circular economy.

(4) *Reduction in carbon emissions:* LSPs have taken initiatives for low carbon supply chain integrations. This initiative has a positive impact on LSPs' environmental and financial performance (Qian *et al.*, 2019). LSPs are required to take appropriate solutions for carbon emission reduction and to develop strategies for a sustainable environment (Guiffrida *et al.*, 2011; Tang *et al.*, 2015; Aldakhil *et al.*, 2018; Liu *et al.*, 2018). Damco, DHL and TNT are offering green services and reducing carbon footprints through various services (Das and Kulkarni, 2018).

(5) *Use of CNG/Electric fleet:* Many LSPs are making use of CNG vehicles to reduce cost, pollution, and fuel consumption (Gupta *et al.*, 2018). The use of CNG/electric vehicles (fuel-free) helps in reducing the noise level and making the air clean. LSPs are also looking forward to adopting e-vehicles in the coming years (McKinnon, 2010; Liu *et al.*, 2018). Almost all Indian LSPs including Safe Express, CTC freight carriers Ltd. and Sal Logistics Pvt. Ltd., etc. are using more of the CNG vehicles to save cost and fuel.

(6) *Resource optimization:* Due to the scarcity of resources, LSPs are looking forward to the alternative options to use limited resources in an optimum way (Centobelli *et al.*, 2017). Conservation of resources will help in the smooth functioning of logistics operations in the future. LSPs are optimizing resources by making maximum use of natural resources over man-made products (Choudhury *et al.*, 2018; He *et al.*, 2018; Winkler and Zinsmeister, 2019). Om Logistics Ltd. conserves its natural resources by making maximum use of solar light and rainwater harvesting in their warehouses.

(7) *Reduction in fuel consumption:* Less fuel consumption by LSPs is considered as economic, social and environmental initiative (Blanco and Sheffi, 2017). Automobile companies are adding fuel-saving features in new vehicles by using new engine technologies. Moreover, the transition from fuel to electric vehicles is a great initiative for reducing fuel consumption and environmental pollution (Tang *et al.*, 2015; Yao *et al.*, 2015). Although, in India, there are many infrastructural bottlenecks to implement e-vehicles entirely, but the government is working in this direction. Jayem Logistics has significantly contributed towards eco-friendly transportation, reduction in fuel consumption, and pollution.

3. Study of sustainable practices in context to an Indian LSP

Most of the identified sustainable practices from the literature review are in context to both developing and developed countries. There is, therefore, a need to understand and identify the sustainable practices of Indian LSPs more closely to make this study more relevant in the Indian context. A real case illustration on Indian LSP has been discussed to have a thorough understanding of sustainable practices followed by them. The information is collected based on multiple visits and discussions with middle and senior management of the case organization.

3.1 Profile of case organization (ABC ltd.)

ABC Ltd. (given name) started its business as a multi-modal transportation organization in the mid-1980s in India. Its objective is to provide logistics support to the manufacturing organizations in the nation as well as across boundaries. With an annual turnover of around INR 1,500 crores (the US$ 225.47 million), it serves all the significant businesses sectors such as automobile, hardware, telecom, retail and pharmaceuticals.

The organization has a wide distribution network of more than 3,500 client base of domestic, transnational, and international presence majorly in the corporate B2B sphere. It provides service to most of the automobile manufacturers and more than 2000 auto segment part producers in India. Their customer base includes all significant brand names like Mahindra and Mahindra, Maruti Suzuki India Ltd., SUZUKI Motors, India Yamaha Motors Pvt. Ltd., Toyota, Daimler, Honda Motors India, Heromoto Corp, Tata Motors, Samsung Electronics India Limited, VIVO Mobiles India, Bharati Airtel, Cadila Pharmaceuticals, Arvind Fashions, etc. ABC Ltd. is conferred with many awards, recognitions, and excellence awards for its outstanding contribution to the logistics sector both in domestic and international services.

3.2 Organizational assets

ABC Ltd. ensures timely delivery and assured services to the clients through its technologically advanced assets. The organization offers modernized multi-client and dedicated warehousing spaces over more than 100 locations with its captive warehousing strength of more than 20 lac square meters in PAN India. It manages hub and spoke distribution through more than 40 Cross-Dock centers and 700 branches for Part Truck Load (PTL) distribution. This Indian LSP delivers more than 14,000 pin codes pan India and is serving over 85 countries through its own offices, joint ventures, exclusive partners, etc.

The case organization offers door to door customized deliveries through more than 4,500 modern technologically advanced, all-weather containerized vehicles of varied capacities ranging from 0.5 metric tons to 40 metric tons. It has more than 5,000 trained workforce, who work sincerely 24 by 7 for committed services, and customer query resolution. ABC Ltd. is equipped with advanced in-house created applications and SAP software along with ORACLE based databases for providing timely and accurate information to all stakeholders. It also uses modern advanced information technology tools and real-time applications to track and trace consignments through owned servers.

3.3 Organizational processes

The organization's order processing is made effective with invoice creation on behalf of their customers, while also creating and managing receipts for storage and dispatch of shipments, and sales tax or excise duties. It also incorporates key parameters like time and motion studies for optimization of resources, designing of warehouse layout, 5S support, and adaptable stock piling arrangements by using the latest and coordinated IT tools for the smooth functioning of warehouses. For managing inventory, the organization prefers to arrange their stocks by using concepts of LIFO (Last in First Out), FIFO (First in First Out), etc. This LSP also encourages the usage of mathematical models along with IT tools for analyzing the inventory costs, transportation costs, and stock management.

An ideal mix of roadways, railways, and the airways are offered by the organization to handle customer consignments and to serve them as per commitments. It offers flexibility to the customers in terms of selection of cargo, selection of location, the type of product and the size of shipments. This LSP also provides value-added services which include services like labeling and kitting of goods, packaging with bubble wrap or directly in carton boxes, and

sorting of goods. Document maintenance, packaging redesigning, consultancy on supply chain optimization, and return logistics are also provided.

3.4 Sustainability measures

In order to conserve natural resources, ABC Ltd. is carrying out numerous activities to manage resources at the ecological, societal and economic levels. The organization is also certified with ISO 14001:2015 certifications for maintaining green practices for sustainability.

Some of the sustainable practices that it follows are as under:

(1) *Reduction in carbon emissions:* All the trucks are outfitted with GPS technology which helps in tracking the exact location, while also enabling reduction in carbon emissions. The organization takes exceptional consideration for vehicles which have valid pollution check and carbon emission certificates.

(2) *Green practices:* ABC Ltd. plants more than 5,000 trees annually to enhance green cover around their warehouses. There is a culture of planting tree saplings on various occasions as a step towards environmental conservation. Air sanitizing plants are also grown around warehouses or distribution centers to purify the air and make surroundings clean.

(3) *Digitalization of processes:* The case organization is adopting process automation, in order to change its manual transactions to digital processes. This initiative not just reduces the use of paper and makes document handling easier but also brings transparency to the system.

(4) *Use of solar energy:* To optimize resources, ABC Ltd. has adopted proper conservation of natural resources. Additionally, the organization has installed solar panels on the roofs of most of the warehouses to generate power and to give back to society by saving electricity.

(5) *Use of natural/Renewable resources:* With preference to use natural light, the organization has built transparent roofs at their facilities. This reduces carbon emission and helps in saving electricity.

(6) *Rainwater harvesting:* Committed to green practices, ABC Ltd. utilizes rainwater stored in its underground tanks for further use in washing vehicles, cleaning the floors, or gardening purposes.

(7) *Education initiatives:* In line with PMKVY (Prime Minister Kaushal Vikas Yojna, Government of India scheme), the organization is running its non-profit education and training institute to increase employability of individuals in the logistics industry. Under this initiative, it offers various short term courses related to logistics and supply chain along with practical training sessions. The meritorious candidates are offered to work with the organization according to their abilities and domain knowledge.

(8) *Healthy working environment:* Offering employee friendly policies and environment, this LSP provides its employees with flexible working hours. In order to provide a comfortable and sound environment, residential and mess services are provided to the employees.

3.5 Selection of sustainable practices

After identifying thirteen sustainable practices from the literature review and case analysis, a dedicated team of three experts with over ten years of experience and working with leading

Indian LSPs, helped in finalizing the sustainable practices in Indian context. In order to achieve this, a list of all identified sustainable practices was shared with experts and their inputs were solicited on application of these practices in their respective organizations and ensuing impact on performance. The level of application of these sustainable practices in their organizations helped in understanding the importance of sustainability in Indian context. After expert inputs, nine sustainable practices were finalized. Out of these nine, five were identified from literature, one was from the case study and three were found to be common in both case study and literature review. The final list of sustainable practices after discussing with Indian experts is given in Table 1. As the objective of this study is to evaluate the sustainability index, therefore, the GTMA is applied for evaluating the sustainability index. The detailed research methodology will be discussed in the next section.

4. Evaluation of sustainability index- Graph Theory Matrix Approach (GTMA)

After identifying sustainability practices, a framework for the evaluation of the sustainability index of an LSP is proposed in this study. The Graph Theory Matrix Approach has been applied for the evaluation of the sustainability index, which considers any number of quantitative and qualitative sustainable practices simultaneously. The conventional methods like cause and effect diagram, process flow charts and block diagrams are not

Table 1. Sustainable practices followed by logistics service providers

S. No	Sustainable practices	Description	References	Source
1	Use of recyclable packaging (*S*1)	Using recyclable and reusable raw material for packaging to promote green practices	Gupta *et al.* (2020), Regattieri *et al.* (2019), Centobelli *et al.* (2018), Jilani *et al.* (2018), Lew *et al.* (2018), Sureeyatanapas *et al.* (2018), Chhabra *et al.* (2017)	Literature review
2	Use of renewable energy sources (*S*2)	Making use of renewable resources for long term sustainability	Taşçıoglu and Keser (2019), Fontes, and Freires (2018), Gupta *et al.* (2018), Piecyk and Björklund (2015), McKinnon (2010)	Literature review and Case study
3	Green procurement (*S*3)	Using green practices for purchasing	Centobelli *et al.* (2018), Teixeira *et al.* (2018), Meehan and Bryde (2011)	Literature review
4	Reduction in carbon emissions (*S*4)	Reducing carbon emission to protect the environment	Aldakhil *et al.* (2018), Centobelli *et al.* (2018), Gupta *et al.* (2018), Lew *et al.* (2018), Tang *et al.* (2015), Guiffrida *et al.* (2011)	Literature review and Case study
5	Use of CNG/ Electric/ hybrid fleet (*S*5)	Using Eco-friendly fleet to reduce the pollution and consumption of fuel	Liu *et al.* (2018), Gupta *et al.* (2018), McKinnon (2010)	Literature review
6	Resource optimization (*S*6)	Optimum use of available resources for long term business continuity	Winkler and Zinsmeister (2019), He *et al.* (2018), Choudhury *et al.* (2018), Centobelli *et al.* (2017)	Literature review
7	Digitization of processes (*S*7)	Adoption of paperless processes and use of latest technologies	Singh *et al.* (2019)	Literature review and Case study
8	Rainwater harvesting (*S*8)	Using rainwater for gardening or washing vehicles	Gupta *et al.* (2018)	Case study
9	Reduction in fuel consumption (*S*9)	Reducing the consumption of fuel for conserving resources	Blanco and Sheffi (2017), Yao *et al.* (2015), Tang *et al.* (2015)	Literature review

suitable for further mathematical analysis whereas this method establishes the directional relationship among variables and also take care of their interdependencies by mathematical analysis (Raj *et al.*, 2010; Jain and Raj, 2016; Hudnurkar; Ambekar, 2019).

It is a more preferred approach over conventional methods for representation and quantification. Digraph assists in the graphical representation of variables, which supports better visual analysis and provides valuable inputs for mathematical modeling. Many researchers have applied the GTMA in different fields. Franceschini *et al.* (2006) have used this approach for finding the quality index. Darvish *et al.* (2009) applied GTMA for the ranking of contractors. Attri *et al.* (2014) used this method to compute the intensity of TPM (Total Productive Maintenance) barriers. Apart from manufacturing, many authors have applied this approach in diversified areas such as to model the various mechanisms required for supply chain coordination (Kaur *et al.*, 2006), to evaluate the technology-based self-service banking service quality (Sindhwani and Goel, 2015), to analyze disposition decisions in reverse logistics (Agrawal *et al.*, 2016), to find the agility index of supply chains (Singh *et al.*, 2017), for quantifying the barriers in the implementation of technologies (Bhandari *et al.*, 2019) and to measure the flexibility index for supply chains (Singh and Kumar, 2019), etc.

It is found to be a very important decision-making tool that helps in creating associations among variables and evaluating by forming an index. Based on the literature review and case study, nine sustainable practices have been identified in this study as shown in Table 1. This approach includes various steps of developing a digraph between variables depending upon their mutual correlations. The research methodology framework is shown in Figure 1. Further, a permanent function is computed by developing a permanent matrix by using Equation (1).

4.1 Variables digraph

The sustainable practices adopted by LSPs are represented in the form of nodes and edges by developing a variable digraph as shown in Figure 2. The nodes represent the sustainable practices and the edges represent their linkages. S_i shows the inheritance of practices and s_{ij} shows the degree of dependence of jth practice on ith practice. It also indicates the directed edge from node i to node j. The linkages among all sustainable practices taken in this study are shown in Figure 2. The digraph for detailed analysis has been discussed in Figure 3.

The permanent function of sustainable practices (Perm S) shown in Figure 3 is written as:

$$\text{Perm } S = \begin{vmatrix} S1 & s_{12} & s_{13} & s_{14} & s_{15} & s_{16} & s_{17} & s_{18} & s_{19} \\ s_{21} & S2 & s_{23} & s_{24} & s_{25} & s_{26} & s_{27} & s_{28} & s_{29} \\ s_{31} & s_{32} & S3 & s_{34} & s_{35} & s_{36} & s_{37} & s_{38} & s_{39} \\ s_{41} & s_{42} & s_{43} & S4 & s_{45} & s_{46} & s_{47} & s_{48} & s_{49} \\ s_{51} & s_{52} & s_{53} & s_{54} & S5 & s_{56} & s_{57} & s_{58} & s_{59} \\ s_{61} & s_{62} & s_{63} & s_{64} & s_{65} & S6 & s_{67} & s_{68} & s_{69} \\ s_{71} & s_{72} & s_{73} & s_{74} & s_{75} & s_{76} & S7 & s_{78} & s_{79} \\ s_{81} & s_{82} & s_{83} & s_{84} & s_{85} & s_{86} & s_{87} & S8 & s_{89} \\ s_{91} & s_{92} & s_{93} & s_{94} & s_{95} & s_{96} & s_{97} & s_{98} & S9 \end{vmatrix}$$

4.2 Quantification of S_is and s_{ij}s

To find out the value of the permanent function (Perm S), there is a need to quantify S_is and s_{ij}s. The qualitative measure of inheritance of practices (S_i) is rated on a scale of 1–5 by experts by considering 1 to be the lowest and 5 to be the highest. The qualitative measures of interdependencies among sustainable practices (s_{ij}) have been quantitatively measured by finding the relative dependence on each other based on the value assigned by experts and

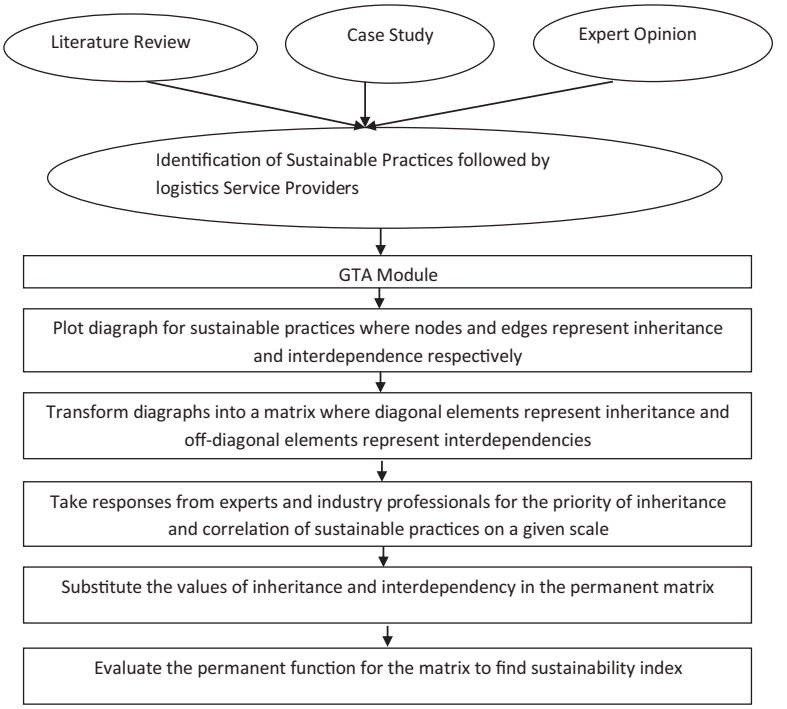

Figure 1.
Research methodology framework

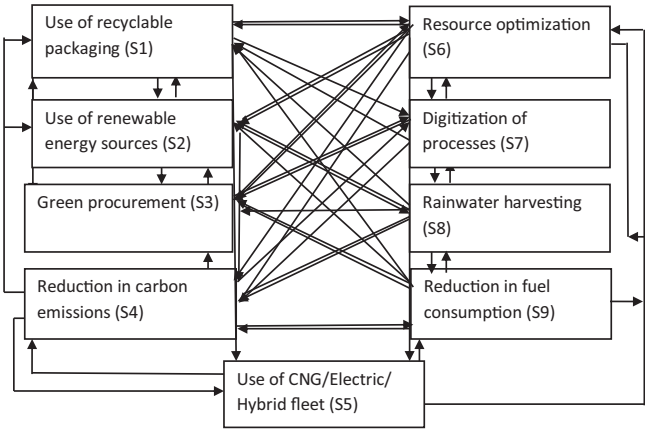

Figure 2.
Interaction among sustainable practices followed by LSPs

discussed in Table 2. A structured questionnaire was designed and sent to all concerned. The experts have been asked to respond on the importance given to sustainable practices (*S*1 to *S*9) and also to rate the relative dependence of one sustainable practice on another according to criteria given in Table 2. For instance, s_{12}- dependence of sustainable practice 2 on sustainable practice 1 which means the degree of dependence of use of energy renewable resources (*S*2) on use of recyclable packaging (*S*1) and similarly, the relative dependence will find for all other possible combinations.

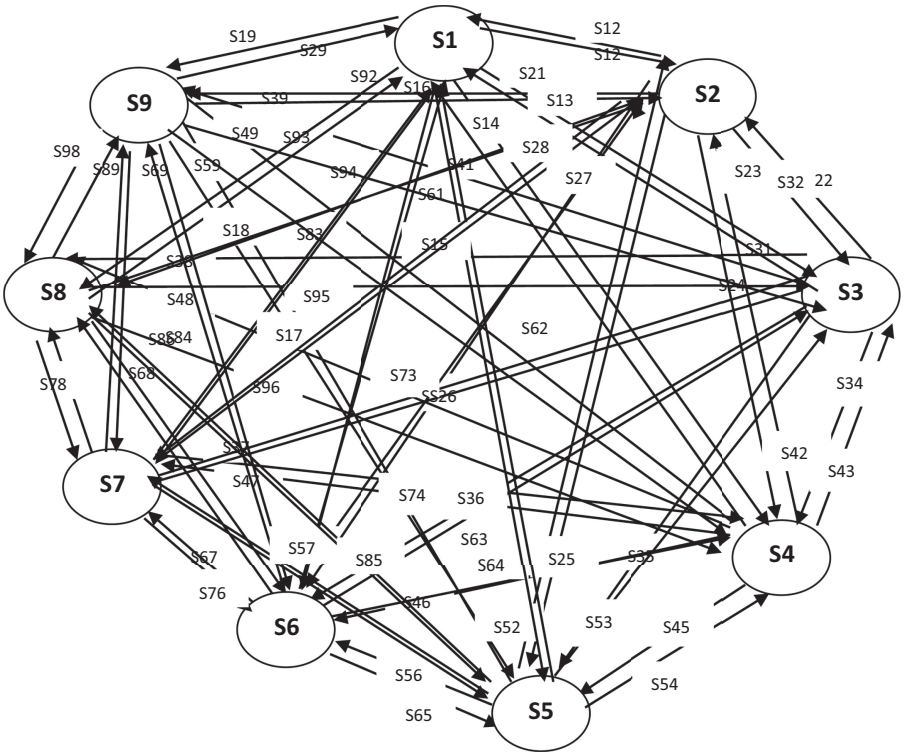

Figure 3.
Digraph representation of elements of permanent matrix

Qualitative measures of interdependencies	s_{ij}	Relative dependence of sustainable practices s_{ji} = 10-sij
Two attributes are of equal importance	5	5
One attribute is slightly dependent on the other	6	4
One attribute is very dependent on the other	7	3
One attribute is most dependent on the other	8	2
One attribute is extremely dependent on the other	9	1
One attribute is exceptionally dependent on the other	10	0

Source(s): Muduli *et al.* (2013)

Table 2.
Relative dependence of sustainable practices (s_{ij}s)

4.3 Variables' permanent matrix

The permanent function is a mathematical expression which helps to determine the sustainability index of LSPs. The calculation for the permanent function is almost the same as finding the determinant of the matrix but considers only positive terms. The value of the permanent function of sustainable practices (Perm *S*) is computed by using Equation (1) which is given as follows.

$$
\begin{aligned}
perm S = {} & \prod_{i=1}^{9} Si + \sum_{i=1}^{8}\sum_{j=i+1}^{9}\sum_{k=j+1}^{3}\sum_{l=k+1}^{4}\sum_{m=l+1}^{5}\sum_{n=m+1}^{6}\sum_{o=n+1}^{7}\sum_{p=o+1}^{8}\sum_{q=p+1}^{9}(s_{ij}s_{ji})S_kS_lS_mS_nS_nS_pS_q \\
& + \sum_{i=1}^{7}\sum_{j=1+1}^{8}\sum_{k=j+1}^{9}\sum_{l=k+1}^{4}\sum_{m=l+1}^{5}\sum_{n=m+1}^{6}\sum_{o=n+1}^{7}\sum_{p=o+1}^{8}\sum_{q=p+1}^{9}(s_{ij}s_{jk}s_{ki} + s_{ik}s_{kj}s_{ji})S_lS_mS_nS_oS_pS_q + \\
& \left[\begin{array}{l}
\sum_{i=1}^{6}\sum_{j=1+1}^{9}\sum_{k=j+1}^{8}\sum_{l=i+2}^{9}\sum_{m=1}^{8}\sum_{n=m+1}^{9}\sum_{o=n+1}^{9}\sum_{p=o+1}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{jk})(s_{kl}s_{lk})S_mS_nS_oS_pS_q \\
+\sum_{i=1}^{6}\sum_{j=i+1}^{8}\sum_{k=j+1}^{9}\sum_{l=j+1}^{9}\sum_{m=1}^{8}\sum_{n=m+1}^{9}\sum_{n=m+1}^{9}\sum_{o=n+1}^{9}\sum_{p=o+1}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{jk}s_{kj}s_{li} + s_{il}s_{lk}s_{kj}s_{ij})S_mS_nS_oS_pS_q
\end{array}\right] \\
& + \left[\begin{array}{l}
\sum_{i=1}^{7}\sum_{j=1+1}^{8}\sum_{k=j+1}^{9}\sum_{l=1}^{8}\sum_{m=l+1}^{9}\sum_{n=m+1}^{9}\sum_{o=n+1}^{9}\sum_{p=o+1}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{jk}s_{ki} + s_{ik}s_{kj}s_{ji})(s_{lm}s_{ml})S_nS_oS_pS_q \\
+\sum_{i=1}^{5}\sum_{j=1+1}^{8}\sum_{k=i+1}^{9}\sum_{l=j+1}^{9}\sum_{m=1}^{8}\sum_{n=m+1}^{9}\sum_{o=n+1}^{9}\sum_{p=o+1}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{jk}s_{kl}s_{lm}s_{mi} + s_{im}s_{ml}s_{lk}s_{kj}s_{ij})S_nS_oS_pS_q
\end{array}\right] \\
& + \left[\begin{array}{l}
\sum_{i=1}^{6}\sum_{j=1}^{8}\sum_{k=i+1}^{9}\sum_{l=j+1}^{9}\sum_{m=1}^{8}\sum_{n=m+1}^{9}\sum_{o=n+1}^{9}\sum_{p=o+1}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{jk}s_{kl}s_{li} + s_{ik}s_{lk}s_{lk}s_{kj}s_{ji})(s_{mn}s_{nm})S_oS_pS_q \\
+\sum_{i=1}^{4}\sum_{j=i+1}^{8}\sum_{k=i+1}^{9}\sum_{l=j+1}^{9}\sum_{m=1}^{8}\sum_{n=m+1}^{9}\sum_{o=n+1}^{9}\sum_{p=o+1}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{jk}s_{ki} + s_{ik}s_{kj}s_{ji})(s_{lm}s_{mn}s_{nl} + s_{ln}s_{nm}s_{ml})S_oS_pS_q \\
+\sum_{i=1}^{4}\sum_{j=i+1}^{9}\sum_{k=j+1}^{6}\sum_{l=i+1}^{9}\sum_{m=k+1}^{8}\sum_{n=k+2}^{9}\sum_{o=n+1}^{9}\sum_{p=n+2}^{9}\sum_{q=p+1}^{9}(s_{ij}s_{ji})(s_{kl}s_{lk})(s_{mn}s_{nm})S_oS_pS_q \\
+\sum_{i=1}^{4}\sum_{j=i+1}^{8}\sum_{k=j+1}^{9}\sum_{l=i+1}^{9}\sum_{m=i+1}^{9}\sum_{n=j+1}^{9}\sum_{o=j+1}^{9}\sum_{p=j+1}^{9}\sum_{q=j+1}^{9}(s_{ij}s_{ji})(s_{ij}s_{jk}s_{kl}s_{lm}s_{mn}s_{ni} + s_{in}s_{nm}s_{lk}s_{kj}s_{ji})(s_{mn}s_{nm})S_oS_pS_q + \ldots
\end{array}\right]
\end{aligned}
\tag{1}
$$

Substituting the values of the variables in the permanent matrix and compute the value of the permanent matrix (Perm S) by putting values in Equation (1):

$$
\text{Perm } S = \begin{vmatrix}
S1 & s_{12} & s_{13} & s_{14} & s_{15} & s_{16} & s_{17} & s_{18} & s_{19} \\
s_{21} & S2 & s_{23} & s_{24} & s_{25} & s_{26} & s_{27} & s_{28} & s_{29} \\
s_{31} & s_{32} & S3 & s_{34} & s_{35} & s_{36} & s_{37} & s_{38} & s_{39} \\
s_{41} & s_{42} & s_{43} & S4 & s_{45} & s_{46} & s_{47} & s_{48} & s_{49} \\
s_{51} & s_{52} & s_{53} & s_{54} & S5 & s_{56} & s_{57} & s_{58} & s_{59} \\
s_{61} & s_{62} & s_{63} & s_{64} & s_{65} & S6 & s_{67} & s_{68} & s_{69} \\
s_{71} & s_{72} & s_{73} & s_{74} & s_{75} & s_{76} & S7 & s_{78} & s_{79} \\
s_{81} & s_{82} & s_{83} & s_{84} & s_{85} & s_{86} & s_{87} & S8 & s_{89} \\
s_{91} & s_{92} & s_{93} & s_{94} & s_{95} & s_{96} & s_{97} & s_{98} & S9
\end{vmatrix}
$$

$$
= \begin{vmatrix}
4 & 5 & 9 & 8 & 5 & 9 & 5 & 5 & 9 \\
5 & 3 & 7 & 9 & 6 & 9 & 5 & 8 & 7 \\
1 & 3 & 2 & 9 & 9 & 7 & 9 & 6 & 8 \\
2 & 1 & 1 & 2 & 9 & 8 & 8 & 7 & 9 \\
5 & 4 & 1 & 1 & 4 & 7 & 5 & 5 & 9 \\
1 & 1 & 3 & 2 & 3 & 4 & 9 & 9 & 9 \\
5 & 5 & 1 & 2 & 5 & 1 & 2 & 5 & 5 \\
5 & 2 & 4 & 3 & 5 & 1 & 5 & 2 & 6 \\
1 & 3 & 2 & 1 & 1 & 1 & 5 & 4 & 3
\end{vmatrix}
$$

Perm $S^* = 2,30,595,214,680$

The best possible value of the index can be computed by taking the highest possible value of all variables. The value of inheritance of all sustainable practices is kept maximum, that is, 5 and the diagonal cells of the permanent matrix are kept 5 as maximum. This maximum index can be used as a reference for benchmarking of sustainability performance. Substituting all values in Equation (1) and the maximum theoretical index can be:

$$\text{Perm } S = \begin{vmatrix} 5 & 5 & 9 & 8 & 5 & 9 & 5 & 5 & 9 \\ 5 & 5 & 7 & 9 & 6 & 9 & 5 & 8 & 7 \\ 1 & 3 & 5 & 9 & 9 & 7 & 9 & 6 & 8 \\ 2 & 1 & 1 & 5 & 9 & 8 & 8 & 7 & 9 \\ 5 & 4 & 1 & 1 & 4 & 7 & 5 & 5 & 9 \\ 1 & 1 & 3 & 2 & 3 & 5 & 9 & 9 & 9 \\ 5 & 5 & 1 & 2 & 5 & 1 & 5 & 5 & 5 \\ 5 & 2 & 4 & 3 & 5 & 1 & 5 & 5 & 6 \\ 1 & 3 & 2 & 1 & 1 & 1 & 5 & 4 & 5 \end{vmatrix}$$

Perm $S^* = S^*_{\max} = 3,63,706,047,040$

S^* represents the sustainability index of LSPs. This value of sustainability index can be also used for comparison with other LSPs. It can help them in positioning themselves in terms of the adoption and implementation of sustainable practices. LSPs can analyze the importance and relationships among sustainable practices and can be implemented in their respective organizations for improving sustainability. The maximum value $S^*_{\max}$ represents the maximum index of sustainability that LSPs can achieve by adopting and implementing maximum sustainable measures.

5. Discussion

In this study, the GTMA is used to compute the sustainability index of LSPs. When the resources are limited and the environment is degrading at a very fast pace in the current market situation, the evaluation of sustainability index can help LSPs in finding suitable solutions to adopt and implement sustainable practices in their inbound and outbound processes. It can help LSPs to devise some strategies for improving the adoption and implementation of sustainable practices, in turn, positively impacting the performance of LSPs. The implementation of sustainable practices by LSPs will also help in reducing wastage of resources which further encourages the circular economy.

From the above case illustration, it has been observed that the sustainability index (S) of the given LSP is comparatively lesser than the best possible value of the sustainability index (S^*). This reflects that there is a scope of improvement for an LSP by implementing more sustainable practices in their logistical operations. LSPs can develop strategies for revision in their processes and can plan for improvement in terms of sustainability. On similar lines, Mangla *et al.* (2019) explored the agro-food supply chain by analyzing four Indian dairy-based organizations and developed strategies for improving the supply chain and logistics performance in emerging economies using the GTMA approach.

The sustainability index can also assist LSPs in positioning themselves and comparing them with their peer service providers. LSPs can develop their strategies for improving their performance through increased use of green practices. Several articles on the implementation of sustainable practices have discussed their importance in developing countries. For the successful implementation of sustainable practices, LSPs should come forward to identify the issues related to sustainability implementation and should formulate a proper strategy for handling them effectively. Similarly, Agrawal *et al.* (2016) evaluated the outsourcing index, which is very useful for managers and practitioners in formulating strategies for outsourcing reverse logistics decisions. In Bangladesh, Moktadir *et al.* (2018) applied graph theory for

identifying barriers for implementing sustainable manufacturing practices in the leather industry. They have also suggested that the managers should formulate strategies for optimum utilization of limited resources to reduce wastage. It also validates our findings in context to Indian LSP.

5.1 Managerial implications

The major implication of this study is that LSPs should select factors for evaluating the sustainability index depending upon the prevailing business environment. These factors may vary as per region and sector. Based on the sustainability index, LSPs may choose to find potential areas for improvement and a green logistics strategy can be developed accordingly. Organizations with low sustainability index can identify their weak areas and can work upon them to increase their sustainability index. Organizations with high sustainability index can compare their values with maximum possible value and can further work in the direction to achieve that level. This framework will be helpful for LSPs in benchmarking their performance with global standards in the era of the circular economy.

5.2 Limitations and future scope

In this study, a case analysis has been done for understanding the sustainable practices of LSPs. Findings from a case may vary with change in sector and location. Therefore, for the generalization of these findings, this study can be further validated by taking more case studies on LSPs in different contexts. This work can be extended for small LSPs as the future scope of the existing work. Apart from considered criteria, other sustainability criteria in context to an emerging circular economy can be also considered for further modification of framework. Further, the results can be compared after evaluating the sustainability index by different methods to check the robustness of the framework. The study may be further extended to comparing the sustainability index of logistics companies from developing and developed countries. It will help in the identification and adoption of advanced sustainability practices by LSPs of developing countries for continuous improvement. The study will not only encourage the organizations but also the society to conserve resources and make proper utilization of available resources.

6. Conclusion

In today's business environment of the circular economy, almost every organization is taking initiatives for reducing environmental degradation and increasing the sustainable use of resources. LSPs are continuously exploring innovative and sustainable ways to contribute to society and the environment. Sustainable practices adopted and implemented by various LSPs have been identified from previous studies. The case study method is also adopted to make the current study more relevant and realistic for LSPs. A real case study on an Indian LSP has been presented to clarify their processes and adoption of sustainable practices in their logistical activities. The information is based on observations and discussions with middle and senior management during multiple visits to the case organization.

This study makes two major contributions. The first is the identification of major sustainable practices in the logistics sector. The second is a framework for the evaluation of the sustainability index. The use of recyclable packaging, renewable energy sources, green procurement, carbon emissions reduction, use of CNG fleets, resource optimization, digitalization of processes, rainwater harvesting and reduction in fuel consumption are the major sustainable practices. Although previous studies have explored many performance measurement frameworks, these frameworks are not so relevant in the era of the circular economy. This study included prominent sustainability practices while evaluating the

sustainability index. We have used GTMA approach for evaluation of the sustainability index of LSPs. The application of this framework is illustrated using the real case of Indian LSP. The sustainability index can also help LSPs in formulating strategies to achieve the UN's sustainability goals. It will motivate LSPs to implement green logistics practices in their operations. This framework will also be helpful for LSPs in comparing their performance against global standards.

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About the authors

Anchal Gupta is doing PhD in Management from Delhi School of Management, Delhi Technological University, Delhi, India. Her interest is in Supply Chain Management, Logistics and Service Quality Management. Anchal Gupta is the corresponding author and can be contacted at: anchal.gupta1503@gmail.com

Rajesh Kumar Singh is Professor in Operations Management area at Management Development Institute, Gurugram, India. His areas of interest include Supply Chain Management, Small Business Management and Quality Management. He has published around 125 research papers in reputed international/national journals and conferences. His papers have appeared in journals such as *Production Planning and Control*, *Journal of Industrial and Production Engg*, *Industrial management and Data Systems*, *Singapore Management Review*, *International Journal of Productivity and Performance Management*, *Benchmarking: An International Journal*, *Journal of Modelling in Management*, *Competitiveness Review*, *Journal of Advances in Management Research*, *International Journals of Productivity and Quality Management* etc.