Investigating sustainable development for the COVID-19 vaccine supply chain: a structural equation modelling approach

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Abstract

Purpose – Immunization is one of the most cost-effective ways to save lives while promoting good health and happiness. The coronavirus disease 2019 (COVID-19) pandemic has served as a stark reminder of vaccines' ability to prevent transmission, save lives, and have a healthier, safer and more prosperous future. This research investigates the sustainable development (SD) of the COVID-19 vaccine supply chain (VSC).

Design/methodology/approach – This study investigates the relationship between internal process, organizational growth, and its three pillars of SD environmental sustainability, economic sustainability and social sustainability. Survey-based research is carried out in the hospitals providing COVID-19 vaccines. Nine hypotheses are proposed for the study, and all the hypotheses got accepted. The survey was sent to 428 respondents and received 291 responses from health professionals with a response rate of 68%. For the study, the healthcare professionals working in both private and public hospitals across India were selected.

Findings – The structural equation modelling (SEM) approach is used to test the hypothesis. All nine hypotheses are supported. This study examines a link between internal processes and organizational learning and the three sustainability pillars (environmental sustainability, economic sustainability and social sustainability).

Practical implications – This study will help the management and the policymakers to think and adopt SD in the COVID-19 VSC. This paper also implies that robust immunization systems will be required in the future to ensure that people worldwide are protected from COVID-19 and other diseases.

Originality/value – This paper shows the relationship between organizational learning and internal process with environmental sustainability, economic sustainability and social sustainability for the COVID-19. Studies on VSC of COVID-19 are not evident in any previous literature.

Keywords Immunization, Sustainable development, Vaccine supply chain, COVID-19 vaccine, Healthcare and hospitals

Paper type Research paper

1. Introduction

Vaccination is one of the effective ways for the prevention of the disease. Millions of people take vaccination to prevent diseases (Chandra and Vipin, 2021). Vaccine supply chain (VSC) involves activities of manufacturing, storage, packaging, cold chain transit, domestic and global shipping, distribution strategies and storage (Sinha *et al.*, 2021). VSC also depends upon individuals' behaviour towards the vaccination. Government plays an important role both on the supply and demand sides. This pandemic has caused a severe threat to human beings and their lives (Ivanov and Dolgui, 2021; Queiroz *et al.*, 2020). Vaccination is an important step to stop the spreading of the COVID-19 pandemic. There was a shortfall of vaccines in the initial phases, and VSC faced many

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problems, but now the conditions have been improved a lot (Alam *et al.*, 2021).

There is a fundamental difference between the pandemic VSC and traditional VSC. Various government agencies directly procured the vaccines from the manufacturer and then distributed them to ordinary people (Chandra and Kumar, 2020). Healthcare experts are looking for vaccine strategies to fight against the pandemic. Many companies are producing vaccines all over the world. COVID-19 vaccines must be produced in vast volumes to cover the whole population (Guntuku *et al.*, 2021). To cover a 100% of the world population, the number of vaccine dosages needed is 2–2.5 times, i.e. 16 to 20 bn doses.

The challenges of VSC are manufacturing challenges, last-mile delivery challenges, cold chain challenges, temperature control, storage capacity, infrastructure, stock management and vaccine management. Developing a cost-effective vaccine is essential for successfully eliminating the dangerous COVID-19 pandemic (Euser *et al.*, 2022). Vaccination expenses and inadequate funding for vaccine purchase in manufacturing and maintaining a cold chain limit vaccine creation and dissemination. Many vaccines are required to vaccinate the world's population (Groom *et al.*, 2022). A significant challenge limiting vaccination programmes worldwide is the restricted number of companies that can successfully create better vaccines. The distance between vaccine stores and vaccination camps can hurt vaccine allocation programmes (Graham, 2020). Insufficient planning can affect immunization enrolment, vaccine buy, collection and distribution. Delays in taking the purchase decisions of the vaccine may increase the deliver lead time (Daniel *et al.*, 2022). In remote locations, a lack of a proper storage system can cause vaccine delivery to be delayed, possibly reducing the value of the COVID-19 VSC. Temperature is a component in some COVID-19 vaccines (Warner *et al.*, 2022). Failure to manage the advised temperature while transferring vaccines from manufacturer to the consumer may decrease VSC efficacy, particularly in tropical areas.

The COVID-19 vaccine must be stored at temperatures ranging from −60 to −90 C, which requires the use of specialized transportation and storage channels to keep the vaccine temperature stable (Dai and Song, 2021). Because of the high demands and high supply in the early days will be an easy target for theft, vaccine logistics necessitates secure loading and careful planning to avoid misappropriation and theft. Panic can lead to manipulation and robbery in the supply chain (SC) (Parikh *et al.*, 2021). For effective vaccines, vaccine manufacturers methods applied shall ensure distribution systems in a complicated web of stakeholders, including manufacturers, public health officers, distributors, pharmacists and others. It will aid in forecasting demand and improve vaccine delivery just in time (Asundi *et al.*, 2021). Manufacturers must work with stakeholders to exchange data such as possible accurate delays, expected delivery dates and the number of vials shipped to model the SC (Almars *et al.*, 2022). Most vaccines require at least two doses, which simplifies transportation and supply.

Though the study is related to the VSC of COVID-19, in the initial phases of any other pandemics, the situations and the issues to another vaccine may be the same as faced in the COVID-19 VSC. The study aims to find the sustainable development (SD) for the COVID-19 VSC, but the study's findings would also apply to other types of pandemic situations. SD is the need of the world. Therefore, the study attempts in this direction that not only focuses on the SD of COVID-19 VSC, but the take away will be for other SCs also. Further, the VSC is affected in different situations like man-made disasters like terrorism and natural disasters like tsunami, cyclones and earthquakes. So, the study can guide in these situations also.

Sustainability focuses on the satisfaction of today's needs without compromising future generations' ability to satisfy their needs (Chandra and Kumar, 2021). There are three pillars: economic, environmental and social, and the concept of sustainability is informally referred to as profits, the planet and people (Nagariya *et al.*, 2022). There has been an increase in investments in the area of SD by the industries in the near future (Falebita and Koul, 2018). SD and the performance of the firms are interlinked with each other (Hsu *et al.*, 2017). SD can help the organizations improve partners' relations, solve labour problems and increase the firm's reputation (Lee, 2012). Achieving sustainability in the VSC is a difficult task. VSC is the backbone of the vaccination program. Therefore, it is essential to improve the VSC performance, which will be the first step towards achieving SD in the COVID-19 vaccine programme.

There have been reduced deaths and disease transmission through vaccination in the past decade (Rappuoli and Hanon, 2018). Vaccination has provided an SD in the healthcare sector by reducing the burden of the deaths caused due to various diseases (Largeron *et al.*, 2015). An increasing number of infections in children, adults and the elderly have been protected against vaccines. The research objective of this paper is as follows:

1. Identify the factors that can help sustain SD in the COVID-19 VSC.
2. This study identifies and examines the link between internal processes and the three sustainability pillars (environmental sustainability, economic sustainability and social sustainability).
3. This study identifies and examines the link between organizational learning and the three sustainability pillars (environmental sustainability, economic sustainability and social sustainability).

This paper discusses the factors that can lead to SD in the COVID-19 VSC. Five variables are identified: internal process (IPR), organizational learning (OL), environmental sustainability (ENS), economic sustainability (ECS) and social sustainability (SS). Nine hypotheses are proposed for this study. Data are collected from those hospitals where the COVID-19 vaccines are given to the population. We have used exploratory factor analysis (EFA), confirmatory factor analysis (CFA) and structural equation modelling (SEM) in this study. SEM is used to analyse the structural relationship and test the proposed hypothesis. The software used is SPSS 20.0 and AMOS 22.0. This study found that internal and organizational learning play an important role in creating an SD for the COVID-19 VSC. This study will create awareness among health professionals to develop a sustainable COVID-19 vaccine.

The rest of the paper is arranged as follows: section two discusses literature review, section three hypothesis development, section four research methodology, section five data analysis, section six discussion and section seven conclusion.

2. Literature review

2.1 Vaccine supply chain

VSC is a network of activities involved in implementing vaccines from the procurement stage. VSC functions include proper management of the cold chain, vaccine inventory, transportation, training of the healthcare workers and adequate management of vaccine distribution (Gupta *et al.*, 2013). Nations around the globe have started providing vaccines to limit the transmission of the pandemic. Availability and proper distribution of vaccines is a big challenge for developing countries like India (Laxminarayan and Ganguly, 2011). The government is planning strategies so that the production of the vaccine and the delivery of the vaccine is increased. The vaccine needs to go through multiple phases before it reaches the population (Sallam, 2021). Phase 1 is a pre-clinical stage in which research is done into foreign substances that induce an immune reaction within the body, natural or synthetic antigens. Phase 2 defines the number of doses and studies to determine the most effective dose and increase the vaccine's safety experience. Phase 3 determines how efficient the vaccine is, and the dose to verify its effectiveness is given to volunteers. Phase 4 is the approval of the regulations and licencing (Lydon *et al.*, 2017).

Strengthen delivery to ensure that high-quality vaccines are always available, stored and distributed under the right conditions in the right amount and form at the right time and in the right place (Georgiadis and Georgiadis, 2021). Promote integration with other SC to provide primary healthcare more efficiently. Invest in systems and infrastructure to manage vaccine waste safely, to process and disposal to reduce its environmental impact. Functional SC and logistics systems build on successful immunization programmes (Bamakan *et al.*, 2021). These systems allow the storage, distribution, handling and management of vaccines effectively, guarantee rigorous cold chain temperature control and use logistics information management systems to support resilient and efficient system performance (Carvalho *et al.*, 2019). The ultimate objective is to ensure that quality vaccines are available continuously between manufacturers and levels of service provision, so that vaccine options are not missed as the vaccines are not available. During vaccine development, it is necessary to check its effectiveness on humans (Goodwin, 2021).

A rapid vaccine roll-out is considered a game-changer and allows the economy for recovering more quickly. Guttieres *et al.* (2021) studied the vaccine's distribution and allocation in the downstream VSC. Jarrett *et al.* (2020) suggested a framework for the VSC traceability to check the counterfeiting in the vaccines. Rele (2021) identified the gaps and the opportunities for combating vaccine development. Alam *et al.* (2021) investigated the challenges in the COVID-19 VSC.

2.2 Sustainable development

Firms need to focus on economic, environmental and social values to achieve SD (Dos Santos *et al.*, 2019). There was strong evidence that developing and promoting business practices that are socially and environmentally capable will probably help organizations raise their income because a sustainable approach is undoubtedly essential to the recognition and activities of clients (Chang and Cheng, 2019; Xu and Gursoy, 2015). In healthcare firms, SD has a significant position. It is essential to assess the organisation's goals to achieve sustainability (Wang *et al.*, 2018). Sustainability is defined as the evaluation as a way to improve the understanding and logical translation of the sustainable means; incorporate sustainability issues into policy processes through recognition and surveying influences in sustainability (past or potentially future) and foster the achievement of sustainability targets (AlJaberi *et al.*, 2020). Different literature has reported different procedures for distinguishing, screening and evaluating the advancing of organizations, including benchmarks and codes, overall performance measurements for sustainability and metrics for sustainability (Lopes de Sousa Jabbour *et al.*, 2020).

COVID-19 is causing widespread human suffering, destabilising the global economy and upsetting the lives of billions of people around the world (Cawthorn *et al.*, 2021; Jones and Comfort, 2020). There was a significant improvement in the health of millions of people before the pandemic. Significant steps have been taken to increase life expectancy and reduce life risk. However, more efforts are necessary to eliminate a broad range of diseases and address a wide range of health problems (Bamakan *et al.*, 2021). By focussing on more efficient health system financing, improved hygiene and healthcare, and improved access to physicians, significant progress can be made to save the lives of millions of people (Abbasi *et al.*, 2020). Health emergencies like COVID-19 represent a global risk and have demonstrated that preparedness is essential (Golan *et al.*, 2020). The Development Program of the United Nations highlighted huge differences between nations' ability to deal with the COVID-19 crisis and to recover. The pandemic is a turning point in emergencies for health and investment in public services in the crucial 21st century (Ranjbari *et al.*, 2021a, b). SD is a multifaceted and complex concept, and the COVID-19 crisis has highlighted some of its internal contradictions in many ways.

3. Hypothesis development

The difficulty of having consistent research and development (R&D) incentives is exacerbated by vaccine development, which is riskier and more expensive than other pharmaceuticals. The challenge that the COVID-19 vaccine procedure faces is that governments and developers must set standards for valid clinical trials in humans at unprecedented speeds (Forman *et al.*, 2021). Developers may also have to make tough decisions about scraping or delaying vaccine candidates for a disorder whereby the world needs vaccinations. Methodological issues and communication breakdowns in clinical studies can also result in non-representative data, fuelling vaccine hesitancy (Pambudi *et al.*, 2022). As a result, vaccine manufacturers must learn from their mistakes (Orji and Ojadi, 2021; Shweta and Kumar, 2021).

Adequate post-marketing monitoring systems can aid in maintaining vaccine trust and uptake. Governments require processes to closely monitor and evaluate data on vaccine efficacy and adverse events as they are introduced to a population (Kumar *et al.*, 2022). Once again, transparency and accountability and coordination of these procedures are required for success. It is crucial to know which metrics are most helpful in measuring and tracking the quality and effectiveness of a vaccine (e.g. transmission rates, case fatality, adverse effects) and to outline how these data can be noted in real-time to other countries (Chandra *et al.*, 2021; Mio *et al.*, 2021). Efforts were made in some countries to monitor COVID-19 vaccines.

Organizational learning is an essential factor in the vaccination process as it helps improve the VSC so that the vaccines can be delivered to the desired locations (Abbas *et al.*, 2021). It is the responsibility of the policymakers to have an organizational change and introduce innovation, learning training, etc. in the vaccination process (Cawthorn *et al.*, 2021). Healthcare workers who will be providing the vaccine need to be trained so that there is minimum wastage of the vaccine and people get it correctly. The primary objective of the policymakers should be to bring changes in VSCs' internal process. Organizations can consistently build knowledge by investigating new situations. It also stressed that better management of knowledge leads to increased efficiency in the organization (Gold *et al.*, 2001). It has also conferred on the organizations to ultimately reflect the learning and growth environment in product and process innovation (Moyano-Fuentes *et al.*, 2018).

Governments will require significant national revenue generation or external aid to fund COVID-19 vaccines and vaccination programs, including the costs of distribution, administration, record-keeping and surveillance (Choudhary *et al.*, 2021). These financial strains come when many economies are in crisis due to the pandemic (Wouters *et al.*, 2021). Suppose governments in resource-constrained settings divert resources from other vaccination programs or essential healthcare services to pay for COVID-19 vaccines and vaccination programs. In that case, health budgets may be distorted, with long-term adverse health and economic consequences.

Social sustainability is the human side of sustainability and is often recognized as the vaguest and least important field than environmental and economical (Hsu *et al.*, 2017). The social sustainability dimension plays an essential role in healthcare organizations. The role of employees and providers in supporting social sustainability is important (Chang and Cheng, 2019). In a developing economy, firms are dependent on their social sustainability dimensions (Karamat *et al.*, 2019). It can help enhance the performance of the immunization program by reducing unnecessary costs of VSC, such as waste, failed supplies, transportation, etc. This will enable the move towards economic sustainability.

It has been indicated that environmental and social sustainability leads to economical sustainability (Chandra and Kumar, 2021). Banerjee *et al.* (2020) did research, which included data from 41 countries across 2002–2013, showing that eco-sustainable practices have an adverse effect on the company's finances. Furthermore, the results showed that the two main criteria that can help the company benefit from environmental sustainability practising were innovation and waste reductions. The study in selected Indian states indicated that the relationship between the environment and economic performance is bi-directional and positive (Gupta and Racherla, 2018). Lee *et al.* (2015) pointed out that environmental performance positively impacts the competitive advantages for the firms. Thong and Wong (2018) in the study found a positive relationship between economic performance and environmental performance across the various companies of Malaysia. It also noted that more environmental sustainability organizations are likely to meet financial constraints for better fund research and development activities (Banerjee and Gupta, 2019). Organizational learning contributes significantly to SD adoption, and specific organizational skills can dramatically impact overall sustainability performance (Mani and Gunasekaran, 2018; Paulraj, 2011). Cooperation and coordination between various partners have a positive environmental impact (Hong and Guo, 2019).

Recent studies have shown that internal process capacity helps organizations move toward SD. Economic, social and environmental outcomes can be developed in products, administrative structures and commercial technologies (Saunila *et al.*, 2019). Moyano-Fuentes *et al.* (2018) conducted a study showing that a company's process innovation is more involved in environmental sustainability. The driving force for sustainable supply management is management innovation (Koster *et al.*, 2017). Improved internal processes can improve three pillars of sustainability through intelligent technologies (Xu and Gursoy, 2015). Since these metrics can be confirmed over a period of time, continued improvements result in improved performance of the SC.

H1. Organizational learning will have a positive impact on the internal process.

H2. Social sustainability will have a positive impact on economic sustainability.

H3. Environmental sustainability will have a positive impact on economic sustainability.

H4. Organizational learning will have a positive impact on environmental sustainability.

H5. Organizational learning will have a positive impact on economic sustainability.

H6. Organizational learning will have a positive impact on social sustainability.

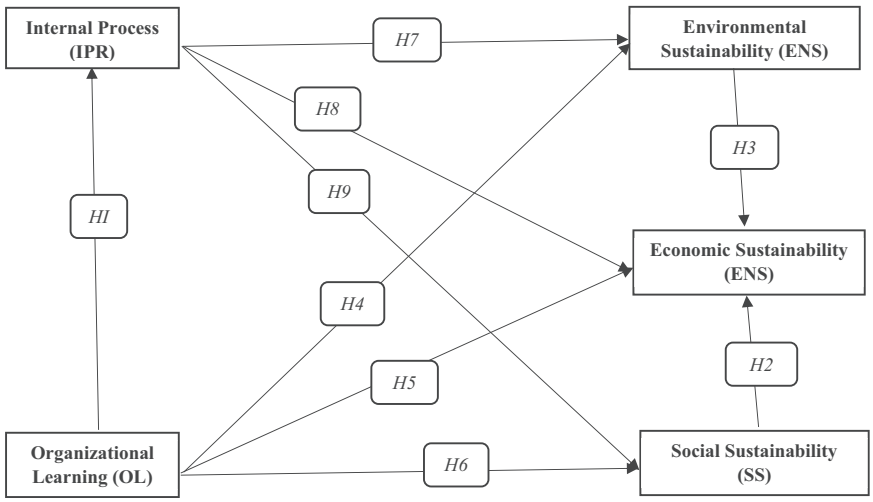
H7. Internal processes will have a positive impact on environmental sustainability.

H8. Internal processes will have a positive impact on economic sustainability.

H9. Internal processes will have a positive impact on social sustainability.

Figure 1 shows the theoretical model for the study. This model uses IPR, OL, ENS, ECS and SS. Nine hypotheses are proposed

Figure 1 Theoretical model



for the study. The first hypothesis proposes a relationship between organizational learning and internal process. The second hypothesis proposes a relationship between social sustainability and economic sustainability. The third hypothesis proposes a relationship between environmental sustainability and economic sustainability. The fourth hypothesis proposes a relationship between organizational learning and environmental sustainability. The fifth hypothesis proposes a relationship between organizational learning and economic sustainability. The sixth hypothesis proposes a relationship between organizational learning and social sustainability. The seventh hypothesis proposes a relationship between internal processes and environmental sustainability. The eighth hypothesis proposes a relationship between internal operations and economic sustainability. The ninth hypothesis proposes a relationship between internal processes and social sustainability.

4. Research methodology

4.1 Research instrument development

Scales have been adapted from prior studies, which had been developed further for the research purpose. The items utilized to measure a particular construct should agree with each other. Also, the items of the constructs should not be matched with other construct items. A seven-point Likert scale on an interval range from "strongly disagree" to "strongly agree" (Baral *et al.*, 2021) was developed for this study for measuring the items, as shown in Table 1. The questionnaire was developed in the English language (Mukherjee *et al.*, 2022). Six numbers of experienced academicians who were subject experts verified the questionnaire.

Table 1 shows the measurement items taken in the study. OL, IR, ENS, ECS and SS were selected from prior studies done. The statement of OL was adopted from Nonaka (1994). The statement of the internal process was adopted from du Toit (2003). The statement of ENS was adopted from Gopal and Thakkar (2016). The statement of ECS was adopted from Green *et al.* (2012). The statement of SS was adopted from Lai and Wong (2012). Each variable is having four or more statements. The variable OL has four OL1, OL2, OL3 and OL4. The variable IPR has six indicators IPR1, IPR2, IPR3, IPR4, IPR5 and IPR6. The variable ENS has four ENS1, ENS2, ENS3 and ENS4. The variable ECS has four indicators ECS1, ECS2, ECS3 and ECS4. The variable SS has SS1, SS2, SS3, SS4 and SS5. OL tries to measure how much improvement and learning is required among the respondents. IPR tries to measure the system and process necessary for VSC and its functions. ENS tries to measure whether the vaccine has any waste and impacts the environment. ECS tries to measure the economic perspective of the vaccine program. SS tries to measure social perspective of the vaccine.

4.2 Sampling and data collection

We have used online and offline surveys to collect data across different places in this research (Pal *et al.*, 2021). Before going for a final survey, we had conducted a pilot survey by taking a sample of 55 respondents. The data collected from the pilot survey were tested for reliability and validity (Kant Pal *et al.*, 2021). The Cronbach's alpha values for all the variables came to be greater than 0.70, which is the accepted threshold level (Hu and Bentler, 1999). After the pilot survey, we sent questionnaires for a final survey to 428 healthcare professionals working in different private and government hospitals where the vaccines are given to the population. Out of 428 questionnaires sent, we have received a sample of 291 responses from the healthcare professionals, with a response rate of 68%. Both the private and government hospitals were selected for the study. To preserve the anonymity of the participants, we have used a random sampling method.

Table 2 shows the demographics of the respondents. In total, 56.01% of the respondents were male, and 43.99% were female. Respondents' education mainly comprises of MBBS (15.46%), MD (12.37%), MS (12.03%), BSc Nursing (17.53%), B. Pharma (12.03%), M. Pharma (9.62%), BSC/BBA in healthcare management (7.90%) and MSC/MBA in healthcare management (13.06%). Respondent's years of experience were 1–5 years (16.15%), 6–10 years (26.80%), 11–15 years (30.24%), 15–20 years (14.09%) and above 20 (12.71%). Respondent's current job position in the hospitals was a chief medical officer (7.90%), doctor (26.46%), medical

Table 1 Measurement items

Variables	Indicators	Statement	Reference
Organizational learning	OL1	It is required to enhance VSC planning, coordination and communication	Nonaka (1994)
	OL2	Need for enhancing employee's productivity	
	OL3	Feedback needs to be obtained from the population after giving the vaccine	
	OL4	There needs to be an improvement in the transparency of VSC	
Internal process	IPR1	Delivery responsiveness needs to be improved	du Toit (2003)
	IPR2	The administration needs to increase the storage capacity	
	IPR3	Vaccine wastage in the process needs to be reduced	
	IPR4	Improved systems and procedures for managing inventory	
	IPR5	Better vaccination services and a more positive attitude among health professionals	
	IPR6	Enhancement of emergency VSC	
Environmental sustainability	ENS1	Need to develop waste management strategies	Gopal and Thakkar (2016)
	ENS2	Non-sharps waste and packaging materials must be reused, recycled, and recovered	
	ENS3	Maximizing the use of reclaimed materials and packaging	
	ENS4	Reduce the amount of vaccine waste from both open and closed vials	
Economic sustainability	ECS1	Investing in and supporting the development of significant immunization infrastructure and services	Green *et al.* (2012)
	ECS2	Reduce the financial consequences of worsening social or environmental conditions	
	ECS3	Maintain changes in immunization programme productivity	
	ECS4	Employees of immunization programmes should be paid more and given more incentives	
Social sustainability	SS1	Reduce the number of health and safety issues that occur	Lai and Wong (2012)
	SS2	Create health and safety committees to assist in the monitoring, collecting feedback, and advice on workplace safety programmes	
	SS3	Reduction of the health and safety effects of vaccine non-compliance and vaccination programme incidents	
	SS4	Courses or training are necessary to improve employee skills and training internal and external	
	SS5	Strong commitment to local communities to better understand the expectations and needs of their development programme	

officer (9.97%), the store manager (14.09%), pharmacist (12.37%), immunization program officer (11.68%) and nurse (17.53%). Types of hospitals, where the survey was conducted, were private hospitals (54.64%) and government hospitals (45.36%).

4.3 Non-response bias and common method bias (CMB)

As the data were collected from February 2021 to July 2021, and therefore, to test the difference between the opinion of early and late responses, a non-response bias test was performed (Mukherjee *et al.*, 2021). To test the non-response bias, 20 replies were collected at the beginning of the survey and 20 responses collected towards the end were considered (Mukherjee and Chittipaka, 2021). The paired sample *t*-test was applied, and the results of paired sample *t*-test showed that there is no difference between the opinion of early and late respondents; therefore, the data can be said to be free from non-response bias. To calculate common method bias for checking the biasness in the data, we have applied the Harman's single factor test. The result showed that the first factor explains 20.517% of covariance, which is below the recommended threshold level of 50% (Podsakoff, 2003).

5. Data analysis

A four-step method is adopted to test the hypothesis and model. First, reliability and validity are measured, followed by EFA using SPSS 20.0. A measurement model is developed where three parameters are measured: convergent validity, composite reliability (CR) and discriminant validity, and at last, the structural model is calculated using AMOS 22.0.

5.1 Reliability and validity (Cronbach's alpha)

Assessment of reliability helps examine the degree of internal consistency between variable measurement items and its freedom of error at any point in time (Jenatabadi, 2015). Cronbach's alpha is used to measure the reliability of the data (Hair *et al.*, 2012). The values should be greater than 0.70, i.e. the recommended level (Nunnally and Bernstein, 1978).

Table 3 shows Cronbach's alpha values for all the items. OL has four indicators OL1, OL2, OL3 and OL4. IR has six indicators IPR1, IPR2, IPR3, IPR4, IPR5 and IPR6. ENS has four indicators ENS1, ENS2, ENS3 and ENS4. ECS has four indicators ECS1, ECS2, ECS3 and ECS4. SS has five indicators SS1, SS2, SS3, SS4 and SS5. The Cronbach's alpha values for OL, IR, ENS, ECS and SS are 0.870, 0.955, 0.884, 0.839 and 0.922, respectively.

Table 2 Demographics of the respondents

Characteristics	Number	%
Gender		
Male	163	56.01
Female	128	43.99
Respondents' educational profile		
MBBS	45	15.46
MD	36	12.37
MS	35	12.03
BSc Nursing	51	17.53
B. Pharma	35	12.03
M.Pharma	28	9.62
BSC/BBA in healthcare management	23	7.90
MSC/MBA in healthcare management	38	13.06
Experience of the respondents in the field of healthcare		
1–5 years	47	16.15
6–10 years	78	26.80
11–15 years	88	30.24
15–20 years	41	14.09
Above 20	37	12.71
Respondents' current position		
Chief medical officer	23	7.90
Doctor	77	26.46
Medical officer	29	9.97
Store manager	41	14.09
Pharmacist	36	12.37
Immunization program officers	34	11.68
Nurse	51	17.53
Type of hospital		
Government	132	45.36
Private	159	54.64

5.2 Exploratory factor analysis

The second step is to perform EFA using SPSS 20.0. Kaiser–Meyer–Olkin (KMO) is being calculated, which came to be 0.821, greater than 0.60 minimum level (Hair *et al.*, 2014). The extraction method is used to group the components. Using the principal component analysis method, all the components are grouped into three components. For the component 1 extracted total variance is 21.524%, followed by component 2 extracted 17.901%, component 3 extracted 13.477%, component 4 extracted 12.184% and component 5 extracted 10.578%. So, the total variance explained by all three components is 75.665%. The next step is to perform the rotated component matrix, which helps group the items in a particular group. Here a total of 23 indicators are grouped into five groups using the varimax rotation method. All the factor loading values are more significant than 0.5, the acceptance level (Watkins, 2018).

Table 4 shows the factor loading for the rotated component matrix. OL has four indicators, and its factor loading values are OL1 has factor loading of 0.835, OL2 has factor loading of 0.902, OL3 has factor loading of 0.908, and OL4 has factor loading of 0.738. IR has six indicators, and its factor loading values are IPR1 has factor loading of 0.870, IPR2 is having factor loading of 0.925, IPR3 has factor loading of 0.944, IPR4 has factor loading of 0.909, IPR5 has factor loading of 0.898 and IPR6 is having factor loading of 0.873. ENS has four indicators, and its factor loading values are ENS1 has factor loading of 0.848, ENS2 has factor loading of 0.884, ENS3 has

Table 3 Cronbach's alpha for the constructs

Construct	Items	Cronbach's alpha
Organizational learning	OL1	0.870
	OL2	
	OL3	
	OL4	
Internal process	IPR1	0.955
	IPR2	
	IPR3	
	IPR4	
	IPR5	
	IPR6	
Environmental sustainability	ENS1	0.884
	ENS2	
	ENS3	
	ENS4	
Economic sustainability	ECS1	0.839
	ECS2	
	ECS3	
	ECS4	
Social sustainability	SS1	0.922
	SS2	
	SS3	
	SS4	
	SS5	

Table 4 Factor loadings of the construct-wise items

Construct	Items	Factor loadings
Organizational learning	OL1	0.835
	OL2	0.902
	OL3	0.908
	OL4	0.738
Internal process	IPR1	0.870
	IPR2	0.925
	IPR3	0.944
	IPR4	0.909
	IPR5	0.898
	IPR6	0.873
Environmental sustainability	ENS1	0.848
	ENS2	0.884
	ENS3	0.891
	ENS4	0.814
Economic sustainability	ECS1	0.800
	ECS2	0.834
	ECS3	0.863
	ECS4	0.772
Social sustainability	SS1	0.890
	SS2	0.849
	SS3	0.848
	SS4	0.872
	SS5	0.894

factor loading of 0.891 and ENS4 has factor loading of 0.814. ECS has four indicators, and its factor loading values are ECS1 has factor loading of 0.800, ECS2 has factor loading of 0.834, ECS3 has factor loading of 0.863 and ECS4 has factor loading of 0.772. SSS has five indicators, and its factor loading values are SS1 has factor loading of 0.890, SS2 has factor loading of 0.849, SS3 has factor loading of 0.848, SS4 has factor loading of 0.872 and SS5 has factor loading of 0.894.

5.3 Measurement model

In this step, CFA is being measured. A model is developed using AMOS 22.0. The developed model has 11 latent variables. Three parameters are measured: convergent validity, CR and discriminant validity. The theoretical constructs developed strongly correlate with the measurement items used in this study. Hence, there is an existence of convergent validity. The research team has evaluated five constructs for their convergent validity using the guidelines. The CR of the constructs should be greater than 0.70 (Hair *et al.*, 2014). The average variance extracted (AVE) for each construct must be greater than 0.50 (Fornell and Larcker, 1981).

The values of CR and AVE are presented in Table 5. The CR value for the construct IPR is 0.964. The CR value for the construct SS is 0.940. The CR value for the construct ENS is 0.919. The CR value for the construct OL is 0.911. The CR value for the construct ECS is 0.890. The AVE value for the construct IPR is 0.903. The AVE value for the construct SS is 0.870. The AVE value for the construct ENS is 0.859. The AVE value for the construct OL is 0.846. The AVE value for the construct ECS is 0.817. Further, we can also observe that all the AVE values are above the recommended value of 0.50 and are satisfying the convergent validity.

Discriminant validity investigates how distinct the constructs are from each other in a proposed model. To assess discriminant validity, the square roots of the AVEs were compared to the correlation for each construct. The selected construct's square root AVE should be greater than the correlations between the specific construct and the other constructs in the model (Fornell and Larcker, 1981). The results are presented in Table 6. All the diagonal items from the table indicate the AVE square root, a measurement of the variance between the structure and the indicators. The off-diagonal elements represent the relationship between the structures. Table 6 shows that the quadrature root of AVE is higher than the correlation between the building structures, which indicates that the discriminant validity of each building in Table 6 can be applied for the structural model testing.

Table 6 shows the discriminant validity matrix. The value variance extracted within the factor of IPR is 0.815. The value variance extracted within the factor of SS is 0.758. The value variance extracted within the factor of ENS is 0.738. The value variance extracted within the factor of OL is 0.715. The value variance extracted within the factor of ECS is 0.668. The value of variance extracted between the factor IPR and SS is 0.787. The value of variance extracted between the factor IPR and SS is 0.787. The value of variance extracted between the factor IPR and ENS is 0.777. The value of variance extracted between the factor IPR and OL is 0.765. The value of variance extracted between the factor IPR and ECS is 0.742. The value of variance extracted between the factor SS and ENS is 0.747. The value of variance extracted between the factor SS and OL is 0.736. The value of variance extracted between the factor SS and ECS is 0.712. The value of variance extracted between the factor ENS and OL is 0.727. The value of variance extracted between the factor ENS and ECS is 0.703. The value of variance extracted between the factor OL and ECS is 0.692.

The next step is to perform CFA to evaluate the model fit of the measurement model to confirm the hypothesized structure. This model is obtained using AMOS 22.0. Table 7 gives the values of model fit for CFA. The measurement CFA model suggested an excellent model fit based on the importance of different common model fit measures presented in Table 7.

Figure 2 shows the CFA model for the latent variables. Five variables are shown IPR, ENS, SS, ECS and OL. Total 23 indicators are there, with each variable having 4 and more indicators. OL has four indicators OL1, OL2, OL3 and OL4. IPR has six indicators IPR1, IPR2, IPR3, IPR4, IPR5 and IPR6. ENS has four indicators ENS1, ENS2, ENS3 and ENS4. ECS has four indicators ECS1, ECS2, ECS3 and ECS4. SS has five indicators SS1, SS2, SS3, SS4 and SS5.

5.4 Structural model

The structural model for the COVID-19 vaccine sustainability is shown in Figure 3. The structural model has 5 variables and 23 indicators. SEM was conducted using AMOS 22.0. The

Table 5 CR and AVE

Constructs	CR	AVE
Internal process	0.964	0.903
Social sustainability	0.940	0.870
Environmental sustainability	0.919	0.859
Organizational learning	0.911	0.846
Economic sustainability	0.890	0.817

Table 6 Discriminant validity

	Variance extracted between factors				
	Internal process	Social sustainability	Environmental sustainability	Organizational learning	Economic sustainability
Internal process	*0.815*				
Social sustainability	0.787	*0.758*			
Environmental sustainability	0.777	0.747	*0.738*		
Organizational learning	0.765	0.736	0.727	*0.715*	
Economic sustainability	0.742	0.712	0.703	0.692	*0.668*

Table 7 Model fit measures for the CFA

Goodness-of-fit indices	Default model	Benchmark
Absolute goodness-of-fit measure		
χ^2/df (CMIN/DF)	2.282	Lower Limit:1.0 Upper Limit 2.0/3.0 or 5.0
GFI	0.949	>0.90
RMSEA	0.05	<0.08
Incremental fit measure		
CFI	0.919	≥0.90
IFI	0.928	≥0.90
TLI	0.908	≥0.90
Parsimony fit measure		
PCFI	0.796	≥0.50
PNFI	0.739	≥0.50

researchers have tested the hypothesis by conducting the SEM using AMOS 22.0, as shown in Figure 3. It can be observed from Table 8 that all the constructs are found to be significant and support the hypothesis.

The goodness-of-fit indices was $\chi^2 = 933.796$ with df = 222, RMSEA = 0.037, CFI = 0.929, TLI = 0.908 and GFI = 0.961, which were within the threshold values suggested by Hu and Bentler (1999). For all the constructs in our model, the fit indices are acceptable. The results of the hypothesis are shown in Table 8. We can infer from Table 8 that all the 5 study variables tested relationships in the final SEM model were statistically significant (see Table 9).

The acceptable model with standardized coefficients for the paths is shown in Figure 3. Five variables are shown IPR, ENS, SS, ECS and OL. Total 23 indicators are there, with each variable having four and more indicators. OL has four indicators OL1, OL2, OL3 and OL4. IPR has six indicators IPR1, IPR2, IPR3, IPR4, IPR5 and IPR6. ENS has four indicators ENS1, ENS2, ENS3 and ENS4. ECS has four indicators ECS1, ECS2, ECS3 and ECS4. SS has five indicators SS1, SS2, SS3, SS4 and SS5. The β value for the hypothesis one is 0.25. The β value for the hypothesis two is 0.78. The β value for the hypothesis three is 0.62. The β value for the hypothesis four is 0.21. The β value for the hypothesis five is 0.12. The β value for the hypothesis six is 0.11. The β value for the hypothesis seven is 0.19. The β value for the hypothesis eight is 0.10. The β value for the hypothesis nine is 0.25.

5.5 Mediation analysis

Table 10 shows the mediation analysis results for the SEM approach. The indirect effect of organizational learning on environmental sustainability with a mediating variable internal process is found to be having complementary mediation with values $\beta = 0.035$ and $p = 0.035$. The indirect effect of organizational learning on economic sustainability with the mediating variable internal process is found to be having no mediation with values $\beta = 0.128$ and $p = 0.229$. The indirect effect of organizational learning on social sustainability with the mediating variable internal process is found to be having complementary mediation with values $\beta = 0.074$ and $p = 0.01$. The indirect effect of the internal process on economic sustainability with the mediating variable environmental sustainability is found to be having complementary mediation with values $\beta = 0.062$ and $p = 0.01$. The indirect effect of the internal process on economic sustainability with the mediating variable social sustainability is found to be having no mediation with values $\beta = 0.151$ and $p = 0.124$. The indirect effect of organizational learning on economic sustainability with the mediating variable environmental sustainability with mediating variable social sustainability is found to be having complementary mediation with values $\beta = 0.097$ and $p = 0.03$. The indirect effect of organizational learning on economic sustainability with the mediating variable environmental sustainability is found to be having no mediation with values $\beta = 0.175$ and $p = 0.236$.

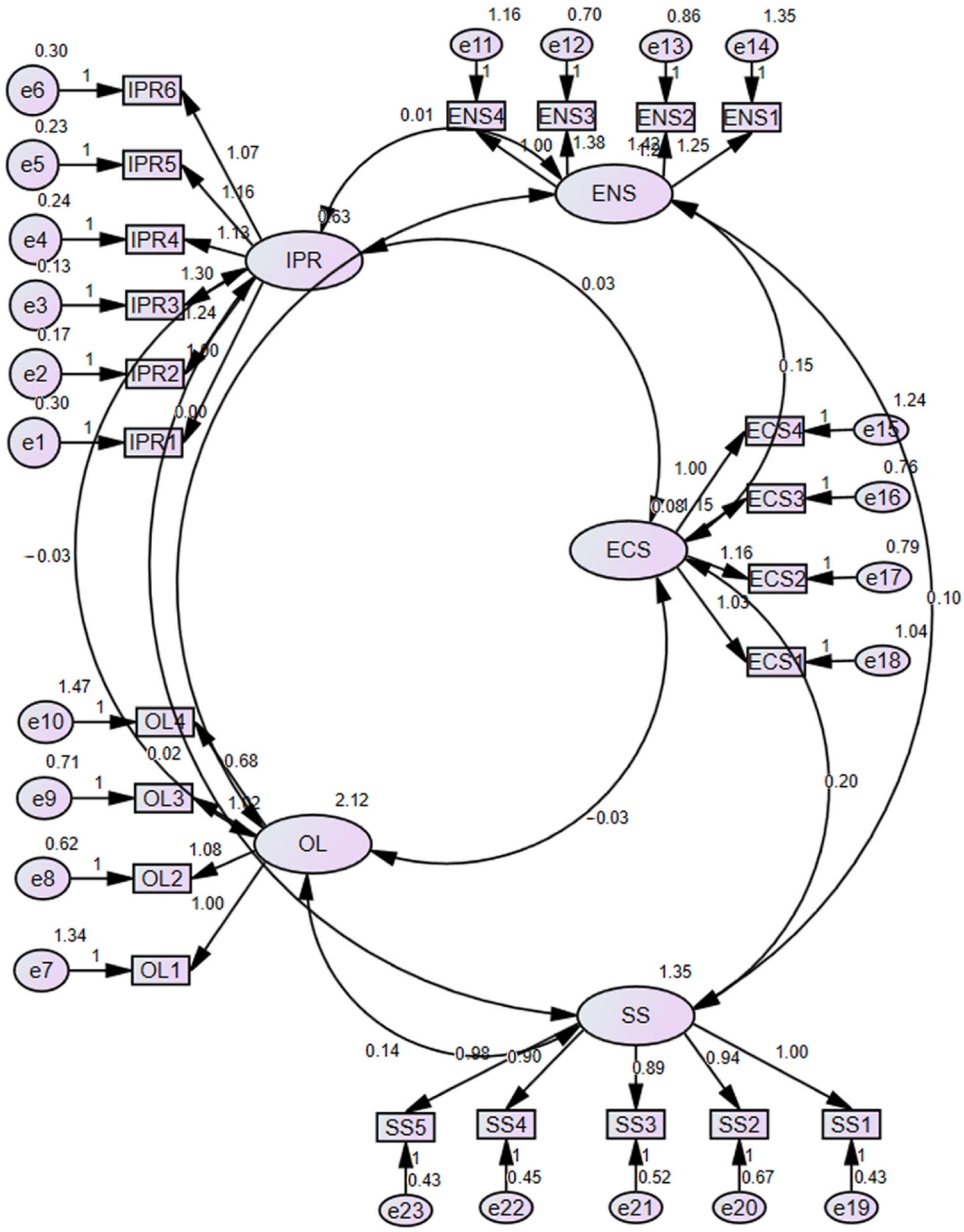
The mediation analysis indicates that social sustainability does not mediate the economic sustainability through organizational learning. While, organizational learning enhances the economic sustainability directly. The internal process does not mediate the economic sustainability through organizational learning. Social sustainability does not mediate the economic sustainability through internal process.

6. Discussion

The objective of this study is to find the impact of SD in COVID-19 VSC. The current outbreak has significantly affected sustainability's economic, environmental and social pillars (Ranjbari *et al.*, 2021a, b). Immunization directly impacts poverty reduction, longer and healthier lives, empowerment of women and long-term stability of the health system (Ranjbari *et al.*, 2021a, b). Most vaccine centres had issues with improper waste management, less training and education, fewer benefits and late salary payments, among other things (Chandra and Kumar, 2021). This will help to motivate healthcare workers and vaccine suppliers while also improving and sustainably managing environmental concerns (Chandra and Vipin, 2021).

Hypothesis 1, organizational learning will impact the internal process, is supported as $\beta = 0.25$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 2, social sustainability will impact the economic sustainability, is supported as $\beta = 0.78$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 3, environmental sustainability will impact the economic sustainability, is supported as $\beta = 0.62$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 4, organizational learning will impact the environmental sustainability, is supported as the $\beta = 0.21$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 5, organizational learning will impact the economic sustainability, is supported as $\beta = 0.12$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 6, organizational learning will impact the social sustainability, is supported as $\beta = 0.11$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 7, internal process will impact the environmental sustainability, is supported as $\beta = 0.19$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 8, internal process will impact the economic sustainability, is supported as $\beta = 0.10$ and $p = 0.000$, so the value of $p < 0.05$. Hypothesis 9, internal process will have an impact on the social sustainability, is supported as $\beta = 0.25$ and $p = 0.000$, so the value of $p < 0.05$.

Figure 2 CFA for the latent variables



In the VSC, like in any other healthcare sector, the organizational learning dimension is critical to the internal process. This should be viewed as the first step toward process improvement, for example, training and educating the healthcare workers regarding various operations of VSC. Healthcare firms need to hire qualified managers and doctors to improve internal processes and provide better infrastructure with modern technologies. Immunization programmes must pay attention to organizational learning to improve internal processes. In India, they are a shortage of trained and educated healthcare workers. There is a lack of modern technology and knowledge-sharing platforms (Chikersal, 2015). WHO indicated a huge shortage of health specialists in developing countries (WHO, 2017). Forecasting accuracy improved (internal process element) as a result of better communications between SC members (organizational learning element), resulting in fewer item shortages (Klemm and McPherson, 2017).

Various studies related to sustainability across many sectors have been discussed which our study. A study conducted in Spanish companies showed a positive relationship between performance and sustainability (Moyano-Fuentes *et al.*, 2018). A survey of sustainable waste management using semi structured interviews methods were carried out in the hospitals of United Kingdom (Nichols and Mukonoweshuro, 2017). Paulraj (2011) measured the sustainable performance in the US firms. Saunila *et al.* (2019) measured sustainability for the small and medium-sized enterprises (SMEs) in the country of Finland. Šūmane *et al.* (2018), this study, highlighted the importance of informal farmer knowledge and learning

Figure 3 Structural model for the COVID-19 vaccine sustainability

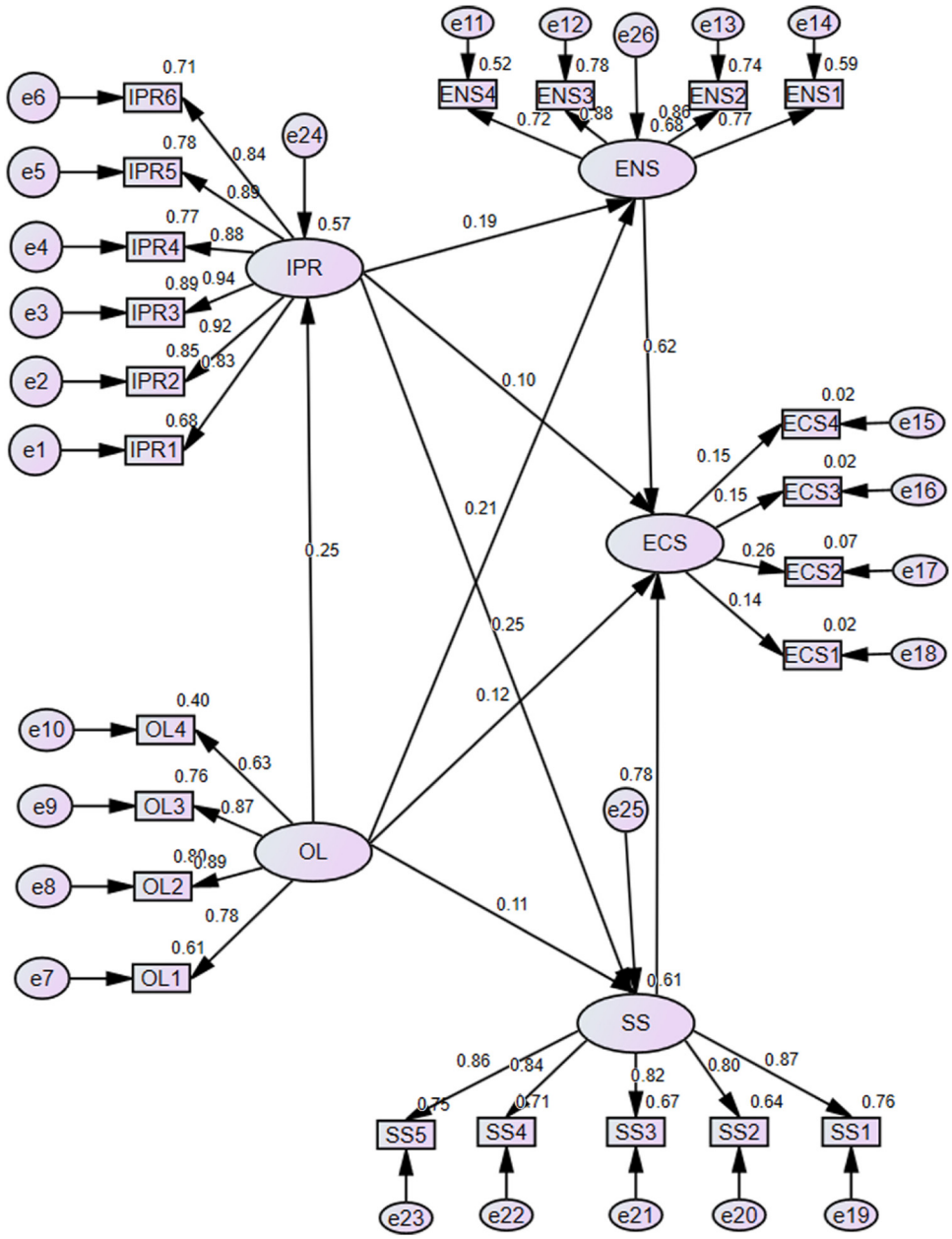


Table 8 Path analysis result for structural model

	Estimate	SE	CR	P	Hypothesis
Internal Process ← Organizational Learning	0.25	0.034	7.35	0.000	Supported
Economic Sustainability ← Social Sustainability	0.16	0.065	2.46	0.000	Supported
Economic Sustainability ← Environmental Sustainability	0.12	0.058	2.06	0.000	Supported
Environmental Sustainability ← Organizational Learning	0.21	0.050	4.20	0.000	Supported
Economic Sustainability ← Organizational Learning	0.12	0.028	4.64	0.000	Supported
Social Sustainability ← Organizational Learning	0.11	0.051	2.16	0.000	Supported
Environmental Sustainability ← Internal Process	0.19	0.090	2.11	0.000	Supported
Economic Sustainability ← Internal Process	0.10	0.049	2.04	0.000	Supported
Social Sustainability ← Internal Process	0.25	0.091	2.75	0.000	Supported

Table 9 Model fit parameters for structural model

Goodness-of-fit indices	Default model	Benchmark
Absolute goodness-of-fit measure		
χ^2/df (CMIN/DF)	4.206	Lower Limit:1.0 Upper Limit 2.0/3.0 or 5.0
GFI	0.932	>0.90
RMSEA	0.037	<0.08
Incremental fit measure		
CFI	0.929	≥0.90
IFI	0.916	≥0.90
TLI	0.908	≥0.90
Parsimony fit measure		
PCFI	0.784	≥0.50
PNFI	0.749	≥0.50

practices in developing alternative agricultural pathways and increasing agricultural resilience. Gopal and Thakkar (2016) examine sustainable SC management practices in the Indian automobile industry and identify the critical factors that will enable it to succeed. Green *et al.* (2012) investigated green SC practices have a significant impact on manufacturing companies' environmental and economic performance. Halati and He (2018) examined the intersection of economic and ecological goals of a focal firm's SD initiatives, which is engaged in the primary activities of production, transportation and storage of a single product within a forward SC. Li *et al.* (2021) conducted a study by Chinese firms to study positive environmental and economic performance relationships of green SC practice. Chege and Wang (2020) investigated the application of environmental sustainability in the SMEs of Kenya. Mota *et al.* (2018) explored a relationship between economic sustainability, environmental sustainability and technology development in the firms of Europe.

A few studies on sustainability in healthcare are being discussed. Fleiszer *et al.* (2015) investigate the idea of sustainability in healthcare innovations. AlJaberi *et al.* (2020) look into sustainability factors in UAE hospitals. Subramanian *et al.* (2020) create a healthcare sustainability index. In the aftermath of the COVID-19 pandemic, Lopes de Sousa Jabbour *et al.* (2020) present trends and concepts of sustainable SC. Matin *et al.* (2021) assess the blood SC's sustainability and resilience. Patil *et al.* (2021) investigate the barriers to humanitarian medical SC sustainability. Stark *et al.* (2020) investigated the long-term improvement of medical activities in Australian hospitals and implemented a medication reconciliation process. The findings of this study will be beneficial to immunization programme policymakers and VSC decision-makers. It will also assist policymakers in determining the most precise and efficient strategy for working internal processes to ensure the long-term success of the COVID-19 vaccine programme.

6.1 Theoretical implications

The study uses the internal process and organizational learning constructs and tries to measure their effect on the three sustainability dimensions: environmental, social and economic sustainability. The construct and its significant impact can be considered critical theoretical contributions in developing sustainable VSC for COVID-19. The statistical validity of these construct strongly supports their significance. Therefore, academicians can consider these factors as primary factors for evaluating any VSC in future.

6.2 Implications for the policymakers

The study suggests that organizational learning significantly impacts internal processes and environmental sustainability. So, the organizations should enhance the learning from the VSC in terms of coordination, communication, transparency and productivity. Further, organizations need to develop proper waste management strategies. The reusable materials should not be disposed of after one use only. The government can also help the organizations by arranging the waste collection from the organizations and can take the fees for waste disposal. The healthcare facilities should also ensure that the vaccine should not be wasted, and this can be achieved by using the full vials of the vaccine. At many places, this problem was identified, and due to it, many vials were not used correctly, and the vaccination mission was affected. So, the policymakers should provide proper training to healthcare workers for using the vials to complete levels and not waste a single drop of vaccine in these challenging times.

The main challenge of the vaccine manufacturing companies was the internal processes related to delivery responsiveness, storage capacity, and system to improve vaccine inventory and enhance vaccine production. All these issues can be solved with the help of improved internal processes by better controlling, monitoring and increasing the productivity of VSC. The government should note from the study for the future to the VSC by providing the storage space, supporting infrastructure to transport the vaccine and managing the raw material. The manufacturing companies cannot develop the necessary infrastructure and cannot quickly procure the materials globally, so the government's support is desired. This support

Table 10 A mediation analysis

	Estimate	P	Hypothesis
Environmental Sustainability ← Internal Process ← Organizational Learning	0.035	0.05	Complementary mediation
Economic Sustainability ← Internal Process ← Organizational Learning	0.128	0.229	No mediation
Social Sustainability ← Internal Process ← Organizational Learning	0.074	0.01	Complementary mediation
Economic Sustainability ← Environmental Sustainability ← Internal Process	0.062	0.01	Complementary mediation
Economic Sustainability ← Social Sustainability ← Internal Process	0.151	0.124	No mediation
Economic Sustainability ← Environmental Sustainability ← Organizational Learning	0.097	0.03	Complementary mediation
Economic Sustainability ← Social Sustainability ← Organizational Learning	0.175	0.236	No mediation

will help procure the materials at the right time, at the correct cost, and ensure the timely delivery of vaccines.

In future, the policymakers should have considered the data provided by the government related to the changes in immunizations, the variants of COVID-19 and the impact of vaccines in different groups. Keeping these changes in mind, the vaccine development programme would achieve a higher success rate in future.

7. Conclusion, limitations and future directions

This research investigates the SD in COVID-19 VSC. Survey-based analysis was carried out in the hospitals where the COVID-19 vaccine is given to the population. Information was collected from the various employees of the hospitals who are associated with the vaccine program. Nine hypotheses were proposed for the study, and all the nine-hypothesis got accepted. Organizational learning and internal process were considered essential factors for the SD in the VSC. After collecting the data, we had used EFA, CFA and SEM to analyse the results. We had used two pieces of software, SPSS 20.0 and AMOS 22.0. The study's findings were that all the proposed hypotheses got accepted, and the structural model satisfied all the parameters. Organizational learning and the internal process had a positive relationship with the three pillars (environmental sustainability, economic sustainability and social sustainability) of SD. Further, this study can be extended to other sectors or countries.

The study's limitations are that the study is conducted in respect of developing country context, so in future, it can be extended to developed countries, and comparative analysis can be done. The sample size was less, so in future, it can be sample size and can be further increased for better results. This study can be compared with other vaccine program already running in the country.

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