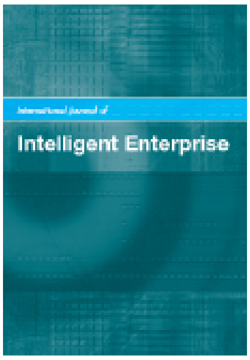

International Journal of Intelligent Enterprise

ISSN online: 1745-3240 - ISSN print: 1745-3232
https://www.inderscience.com/ijie

Study of Indian sector selection problem amidst coronavirus disruption: an AHP approach

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DOI: 10.1504/IJIE.2024.10060775

Article History:

Received:	23 April 2020
Last revised:	15 September 2021
Accepted:	17 January 2022
Published online:	13 December 2023

Study of Indian sector selection problem amidst coronavirus disruption: an AHP approach

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Abstract: As China's position in the market weakens due to the coronavirus disease, supply chain managers are looking for alternatives to safeguard their businesses. India, with its strategic location, infrastructure and growing economy poses a great option. Several industry sectors in India are performing exceptionally well and can tap into the opportunity and showcase their prowess in stabilising the disruptions caused in the global supply chains. However, more investments are required for the development of these sectors to meet the global demand. The challenge that lies with the government is to prioritise sectors for investments. The present study aims at creating a decision-making framework using analytical hierarchy process (AHP) to solve this problem. The three-layer AHP framework, through pairwise comparisons, aims at identifying the sector on which the government should focus its investments upon based upon various performance parameters. The results from AHP depict that the pharmaceutical sector should be given priority in terms of investments for its development followed by chemical, agriculture, aquaculture and textile sector.

Keywords: analytical hierarchy process; AHP; sector selection; India; disruptions; global supply chains.

Reference to this paper should be made as follows: Agarwal, N., Seth, N. and Agarwal, A. (2024) 'Study of Indian sector selection problem amidst coronavirus disruption: an AHP approach', *Int. J. Intelligent Enterprise*, Vol. 11, No. 1, pp.73–84.

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1 Introduction

Supply chain networks are often vulnerable to disruptions because of the turbulence in the global business environment (Agarwal et al., 2021). These disruptions cause undesirable operational and financial outcomes leading to loss of revenue and market share for firms (Chowdhury et al., 2019; Agarwal et al., 2020b). Experts have noted that the disruptions may be due to external, internal or structural factors affecting the supply chain (Kochan and Nowicki, 2018; Pettit et al., 2019). Each factor is, however, equally potent in disrupting the globally interconnected supply chains (Kochan and Nowicki, 2018). The recent turbulence experienced by the firms and their supply chains globally is the COVID-19 pandemic (Belhadi et al., 2021). The disease originated from one end of the world and gradually spread to several countries. It affected millions of people and caused several hundred thousand deaths in all states and territories around the world (WHO, 2020). The governments resorted to border closures and strict regulations that affected logistics and other operational services of several supply chains. The unprecedented situations created due to the spread of the pandemic has made practitioners realise that they must reduce their vulnerability to the factors that cause disruptions. Hence, supply chains are now being designed to incorporate resilience. Resilience provides an efficient and effective response and provides the capability to recover to its original state or a better state, post the disruptive event (Christopher and Peck, 2004).

The resilience of supply chains can be understood from their responsiveness in the face of disruption and can be strengthened through building redundancy or flexibility (Sheffi and Rice, 2005). The concentration of suppliers in few locations had affected the continuity of supply chains when these locations were shut down during the spread of the disease (Belhadi et al., 2021). Therefore, to incorporate resilience through building redundancy and flexibility in the face of disruptions, supply chain managers are considering alternative locations as part of their supply network. India with its strategic location, infrastructure and growing economy poses as a valued alternative for these global supply chains. Several industrial sectors in India are performing at par with the global standards and participate in building the resilience of global supply chains (IBEF, 2021). As an important part, the industrial sectors of India can provide much-needed flexibility to the global supply chains and help in stabilising the turbulence and prevents disruptions. However, to better cater to the global demands, the sectors would need more development that requires require investments from the Indian government. With several sections requiring investments amidst limited resources, choosing a particular industry sector for development amidst conflicting criteria makes the problem a multi-criteria decision-making problem. For the present study, the authors aim to develop a decision-making framework to solve the problem of industrial sector selection that shall define the suitability of prioritising the policy-making towards the development of the sector. Thus, the study ultimately aims to create a decision-making framework that evaluates the suitability of an industrial sector for prioritising policy-making by the government for development.

The objectives of the study are fulfilled by developing a decision-making framework using Analytical Hierarchy Process (AHP). A three-layer hierarchical AHP framework is created that shall help in identifying the sector in which the government should focus its investments (Saaty, 1990). AHP is an approach to decision making that involves structuring multiple-choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives. Through easy and flexible methods, AHP decomposes any complex problem into a structured hierarchy of the problem goal, criteria, and alternatives. It helps decision-makers to choose an optimal solution that best suits the problem's parameters (Gompf et al., 2021). With the advantages of AHP and its ability to avoid inconsistencies, the methodology is suitable for the present study. The results of the study will help the government and policy makers in understanding the performance of the sector and its supply chains for channelling investments. The rest of the study is structured as follows: firstly, a brief about the disruption has been discussed (Section 2) along with its consequence on global supply chains and opportunities to India. The review is followed by the methodology and decision-making framework (Section 3). The study is concluded with the analysis of managerial implications and the future scope of the study (Section 4).

2 Supply chain disruption and India's opportunities

2.1 COVID-19 disruptions and effect on global supply chains

In February-March 2020, the World Health Organization (WHO) designated COVID-19 (or novel coronavirus disease 2019) as a global pandemic. The disease became a leading cause of hundreds of thousands of deaths while infecting millions of people globally. The spread of the disease caused the government to impose strict lockdowns and border regulations. The regulations brought several local supply chains to a standstill. Large global supply chains dependent on them got severely impacted due to expedited premium logistics services and other country-specific operational problems. The negative impact of the pandemic on global firms can be judged from the fact that 78% of the US manufacturing companies have suffered a severe financial impact due to the uncertainty caused by the pandemic (Belhadi et al., 2021). The spread of the disease also caused supply disruptions to cascade down to other manufacturing sectors in less-affected countries. The demand also declined globally along with investment delays thereby creating severe disruptions in global supply chains (Belhadi et al., 2021).

2.2 India's opportunities to the disruptions

The COVID-19 pandemic has made the firms realise the importance of resilience capabilities in maintaining continuity in the face of disruption through efficient and effective response. The large share of few strategic partnerships led to economic spill-overs motivating companies to build more redundancy and flexibility in their supply chains. To this end, firms are seeking alternative locations in their supply network. Alternative locations shall help in containing the disruption, ensuring continuity and provide a competitive advantage. In this endeavour, the Indian sub-continent present in the manufacturing heartland is a suitable alternative. The strategic location of India, growing economy, large market and availability of labour make it an appropriate alternative. There are several industry sectors in both manufacturing and services that have the potential to grow by international standards and fulfil the needs of not only the Indian sub-continent but also of the world. For example, one of the several sectors which have the potential to grow amidst the coronavirus is the Chemical sector. Covering more than 80,000 commercial products, India's chemical industry is extremely diversified (IBEF, 2021). Globally, India is the fourth-largest producer of agrochemicals after the United States, Japan and China. India accounts for ~16% of the world production of dyestuffs and dye intermediates. The domestic chemicals sector's small and medium enterprises are expected to showcase 18-23% revenue growth in FY22, owing to an improvement in domestic demand and higher realisation due to high prices of chemicals. India's proximity to the Middle East, the world's source of petrochemicals feedstock, enables it to benefit on economies of scale (IBEF, 2021). The chemical sector is also benefiting from several schemes and policies provided by the Government of India that makes it more attractive for investments.

Similarly, other industrial sectors like gems and jewellery, textile, agriculture, electronics etc. are also witnessing phenomenal growth and several of them are ranked among the top 5 industrial sectors in the world. These growth trajectories are bolstered by more industrial players in manufacturing and policy support from the government.

2.3 Important sectors of India

India is one of the fastest growing economies in the world. The nation boasts of several industry sectors that have a potential of providing to the international demands. Select primary and secondary industry sectors based on the performance in FY 19-20 are selected for analysis in the present study (Table 1).

The performance of several of the industry sectors of India is at par with that of its global counterparts. However, there are certain factors that inhibit them to meet the global demand such as technology support.

Table 1 Analysis of select industry sectors of India

Parameters/ sector	*Market size*	*Policy support*	*Key trends*	*Research and development*	*Cost advantages*
Pharmaceutical	Industry comprises of biopharmaceuticals, bio-services, bio-agriculture, bio-industry, and bioinformatics. The industry was valued at US $64 billion in 2019. India's medical devices market stood at US $10.36 billion in FY20.	PLI scheme in 13 key pharma sectors with an outlay of US $26.7 million. FDI up to 100% under the automatic route for manufacturing of medical devices subject to certain conditions.	The export from India stood at US $24.4 billion with rising expenditure from the government towards the development of the sector. The FDI inflows in the Indian sector are also increasing steadily	Firms considering Industry 4.0 technologies to reduce valuable start-up capital costs and helps pharma companies build sounder businesses	The cost of manufacturing formulations in India remains 30–40% lower than other comparative manufacturing hubs such as China
Chemicals	The Indian chemicals industry stood at US $178 billion in 2019 and is expected to reach US $304 billion by 2025 registering a CAGR of 9.3%.	The GoI is considering launching a production linked incentive (PLI) scheme in the chemical sector to boost domestic manufacturing and exports. 100% FDI is allowed under the automatic route in the chemicals sector with few exceptions	India's speciality chemicals companies are expanding their capacities to meet the increasing domestic and overseas demand. The imports and exports have seen a steep rise in FY21	Continued R&D efforts in the industry required to improve their quality standards, obtain higher yields and sustainability. The sector has growth potential with increase in technology investments	Basic has high feedstock and raw material costs (low profits) while specialty has high selling and product development costs. Higher costs of finance and poor infrastructure translate into higher costs
Textile	The Indian textiles and apparel industry contributed 2% to the GDP, 12% to export earnings and held 5% of the global trade in textiles and apparel in 2018–2019.	DRDO is helping the Indian textile industry to produce yarns and eliminate dependence on import of Chinese and other foreign clothing for military uniforms. 100% FDI is allowed in textiles. PLI worth INR1.44 billion for man-made and technical fibre	The textiles trade has seen steep increase after suffering a set-back in FY 20 due to the pandemic and has stood at US $26.1 billion. Government is supporting the sector through funding and machinery sponsoring	Technology Upgradation Fund Scheme (TUFS) covering all manufacturing segments of the industry	Low cost of plant and machinery makes manufacturing units viable at all scales. India also enjoys a comparative advantage in terms of skilled manpower
Agriculture	In FY20, the total food grain production in the country was recorded at 296.65 million tonnes—up by 11.44 million tonnes compared with 285.21 million tonnes in FY19.	The government has announced Production Linked Incentive (PLI) scheme for the food processing sector with an incentive outlay of INR 1.5 billion over a period of six years starting from FY 22	Agriculture exports from India have seen a steep increase from FY20 to FY21. A large population and rising urban and rural income are driving demand.	Both domestic and global firms have been focusing on product innovation to cater to domestic tastes, crop protection, soil enhancement, increased productivity	India benefits from a large sized agriculture sector, abundant livestock, high returns and cost competitiveness
Aquaculture	India accounts for 7.58% of the global production. Fish production in the country reached an all-time high of 14.16 million metric tonnes between 2019 and 2020. The fisheries sector contributes 1.24% to the gross value added (GVA) and 7.28% to the agricultural GVA.	the GoI formulated and launched the Centrally Sponsored Scheme on 'Development of Inland Fisheries and Aquaculture'. The total outlay approved for the entire 10th plan period is Rs 135.00 crore.	The industry is among major contributors of foreign exchange with exported value of US $7.08 bn in FY18.	There is a strong need to come up with innovative and cost-effective transportation and storage facilities to ensure supply of superior product to the consumer.	Fragmented due to its labour-intensive nature. Lack of cold storage leads to high costs hence lower their bargaining power.

Source: compiled from data from IBEF reports (2021)

3 Research method

3.1 Sector selection problem

The recent turn of events has caused firms to reconsider how the supply chain networks are designed. The firms are now prioritising resilience that shall enable them to face the disruption and provide continuity of operations. One way of strengthening resilience is to build redundancy and flexibility in operations. These factors were absent in many supply chains while confronting the recent disruption (Sheffi and Rice, 2005). Therefore, firms are considering building their supplier network in multiple different locations. This brings opportunities for several nations to attract investments while also stimulating growth opportunities. India is one such nation that not only has an advantage over other nations in terms of locations and labour but also has an edge in terms of the output of several sectors. However, meeting the global requirements in a better manner requires the development of the infrastructure that consecutively requires investment from the government. With limited resources at hand and several industrial sectors requiring investment, the government has to prioritise the selection of sectors for its development. Selecting a particular sector among multiple sectors for development amidst conflicting criteria makes the problem a multi-criteria decision-making problem. Thus, the present study aims to create a decision-making framework that evaluates the suitability of an industrial sector for prioritising policy-making by the government for its development. In developing a global supply chain network, studies often forget the importance of including the political, economic, social, technological and legal environment that surrounds it. Hence, practitioners can benefit from such a study where the industrial sector is developed considering its macro-economic aspects and performance. Such an attempt consequently improves the attractiveness of the sector for the supply chain managers that are managing global supply chains and are looking for viable alternatives.

The selection of sector (or alternatives available to the government) is based on several aspects (or criteria) which make it a multi-criteria decision-making problem. The present problem shall be solved by the analytical hierarchy process (AHP) method. A few of the categories in the literature, including quality, time, flexibility, and cost have also been developed (Narasimhan and Talluri, 2009). Based on the literature, the performance criteria of a sector are used as criteria for prioritizing the sectors. The criteria decided upon are technology, cost, flexibility, lead time and research and innovation.

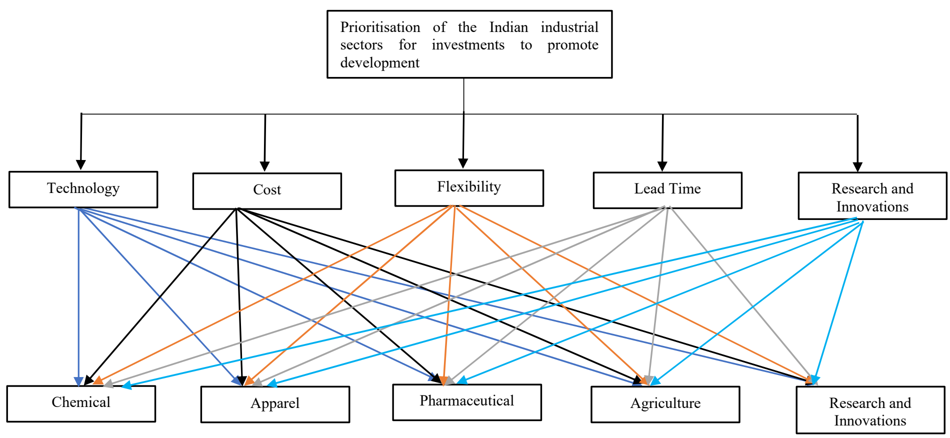
3.2 AHP decision framework

Analytical hierarchy process is a method in multi-criteria decision-making field that helps the designer to select proper solution in complex multi-objective problems (Saaty, 1990). AHP is a powerful tool for measurement through pairwise comparisons and relies on the judgement of experts to derive priority scales. The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute. Some AHP advantages in comparison other MCDM techniques include its acceptance of inconsistencies in managerial judgements/perceptions and its user friendliness. Users may directly input judgement data without further requiring mathematical knowledge but AHP provides a method to check the consistency of the solution and gives an opportunity revise the judgements for obtaining robust and consistent results. In current research work, AHP is applied to prioritise sectors based on the supply chain performance parameters namely- supply chain technology, cost, flexibility, lead time and R&D (research and development) taken from Chowdhury et al.(2019). The decision framework for the current problem is developed through the following steps and are taken from the study of Agarwal et al. (2020a):

3.2.1 Construction of decision-making hierarchy

The decision hierarchy is a graphical representation of the decision goal, the main objectives, the sub-objectives, the risk factors (attributes), and the alternatives. This hierarchic representation and decomposition represent a succinct summary of the decision problem at hand. For the current case, the framework is presented in Figure 1

Figure 1 Pairwise comparison decision framework (see online version for colours)



Here, the top position in the hierarchy is given to the goal of the problem which in the present case is "prioritisation of the Indian industrial sectors for investments to promote development". The goal is based on the performance of the alternatives based on the criteria. The criteria are, hence, placed below the goal as fulfilment of criteria leads to fulfilment of the goal. The criteria in the present decision framework are 'flexibility', 'technology', 'research and innovation', 'lead time' and 'cost'. The alternatives are evaluated based on each of the criteria, therefore, these are placed in the end. The alternatives in this case, which are also the Indian sectors are 'pharmaceutical', 'apparel', 'chemical', 'agriculture' and 'aquaculture'.

3.2.2 Pairwise comparisons

To determine the relative importance of the criteria and the alternatives, the research team subjectively evaluated pairs of these factors (attributes) on a nine-point scale (Table 2).

Table 2 1–9 fundamental scale for pairwise comparison

Priority intensity	*Definition*	*Description*
1	Equally important	Two criteria contribute equally to the objective
2	Weak or slightly important	Experience and judgement slightly favour one criterion over another
3	Moderately important	
4	Moderate plus importance	Experience and judgement strongly favour one criterion over another
5	Strongly important	
6	Strong plus	A criterion is favoured very strongly over another criterion
7	Very strongly important	
8	Very, very important	The importance of one criterion over another is affirmed at the highest possible order
9	Extremely important	

Based on the scale the experts were asked to perform the pairwise comparisons between the criteria and the alternatives. The pairwise comparisons are first performed between the criteria to obtain their priority. The specific question asked from the experts was ‘based on the goal, which performance parameter should be prioritised over the other and by how much?’. An example could be ‘based on the goal, should the lead time performance be prioritised over flexibility and by how much?’. The experts can then provide their opinion based on the 9-point scale. If the former criterion is prioritised then the value of a_i is given else, if the latter criterion is prioritised then $1/a_i$ is given. The pairwise comparison matrix of the criteria is performed in Table III.

Table 3 Pairwise comparison for criteria

	Technology	*Cost*	*Flexibility*	*Lead time*	*Research*
Technology	1	4	0.5	3	2
Cost	0.25	1	0.166667	0.25	0.111111
Flexibility	2	6	1	7	4
Lead time	0.333333	4	0.142857	1	0.5
Research	0.5	9	0.25	2	1

After this calculation, priority of the alternatives is obtained by performing pairwise comparisons between the alternative based on each of the criteria. The specific question asked from the experts was ‘based on the criteria, which sector should be prioritised and by how much?’. An example could be ‘based on the flexibility performance, should the agriculture sector be prioritised over chemical and by how much?’. The experts are again requested to provide their opinion based on the 9-point scale (Chaibate et al. 2021). If the former alternative is prioritised then the value of a_i is given else, if the latter alternative is prioritised then $1/a_i$ is given. The pairwise comparison matrix of the alternatives is performed in Table 4 with respect to the technology criteria.

Table 4 Pairwise comparison for alternative w.r.t criteria technology

Technology	*Pharmaceutical*	*Apparel*	*Chemical*	*Agriculture*	*Aquaculture*
Pharmaceutical	1	3	0.333	2	5
Apparel	0.333	1	0.143	0.25	0.333
Chemical	3	7	1	4	3
Agriculture	0.5	4	0.25	1	4
Aquaculture	0.2	3	0.333	0.25	1

3.2.3 Calculation of priority of alternatives

The priority vector is calculated first for the pairwise comparison matrix of criteria and then for the pairwise matrices of alternatives. A total number of 150 pairwise comparisons were conducted (25 comparisons to develop the weights for the criteria, 125 comparisons to develop the weights for each alternative's performance relative to the criteria). The procedure of obtaining the priority vector involves normalising the nth root of product of each row.

$$A\omega = \frac{\left[\prod_{i=1}^{n} a_{ij}\right]}{\left[\sum_{1}^{n}\left[\prod_{i=1}^{n} a_{ij}\right]^{\frac{1}{n}}\right]}; \qquad i, j = 1, 2, 3, \ldots, n \tag{1}$$

The priority vector for each of the criteria and alternative are depicted in Table 5.

Table 5 Final AHP priority vector for criteria and alternatives

Criteria	*Technology*	*Cost*	*Flexibility*	*Lead time*	*Research*	*Final priority weights*	*Rank*
Sectors	*0.238*	*0.037*	*0.463*	*0.0905*	*0.170*		
Pharmaceutical	0.2296	0.3695	0.3239	0.3608	0.4532	0.3568	I
Apparel	0.0479	0.1072	0.0726	0.0452	0.0360	0.0644	V
Chemical	0.4377	0.2381	0.26996	0.3198	0.2296	0.3326	II
Agriculture	0.1664	0.0616	0.0767	0.1335	0.1571	0.1263	III
Aquaculture	0.0796	0.1098	0.1307	0.0914	0.1088	0.1199	IV

The final priority vector for the alternatives is given by obtaining the sum of products of the priority vector of each criterion with that of the priority vector of each alternative (Table 5).

3.2.4 Consistency check

The consistency of the pairwise comparisons of the criteria and alternatives is assessed to check the credibility of the values filled in the matrices. This is done to make sure that there is no irregularity in assigning relative values to the elements of criteria. By that Saaty meant that we want to make sure that the input to the main matrix is homogenous, and erroneous statements such as A is favourable to B and B is favourable to C but A is not favourable to C do not exist. Consistency ratio (CR) value assesses the consistency of the pairwise comparison matrix. Its value should be less than 0.5 to ensure that the pairwise comparisons are consistent.

$$CR = \frac{CI}{RI}$$

RI is the random index is a direct function of the number of criteria or systems being considered and is obtained from the random index table given in the Table 6.

Table 6 Random index table

	3	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Random index	0.58	0.89	1.11	1.25	1.32	1.41	1.45	1.49	1.51

Source: Saaty (1990)

The consistency index (CI) is obtained by the help of following equation:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

Here, $\lambda_{\max}$ is largest eigenvalue, which is determined by multiplying the sum of each column of pairwise comparison matrix with the weight value (W). The final consistency ratio values for the criteria and the alternative are given in Table 7.

Table 7 Consistency ratio condition

S. no.	*Name of the sector*	*Consistency ratio*	*Condition check*	*Accepted/rejected*
1	Technology	0.436	<0.5	Accepted
2	Cost	0.452	<0.5	Accepted
3	Flexibility	0.387	<0.5	Accepted
4	Lead Time	0.257	<0.5	Accepted
5	Research	0.414	<0.5	Accepted

4 Conclusions

The present study has tried to build a decision framework based on which the policymakers can prioritise the investments in industrial sectors for its development. The investments in these sectors shall help them in attracting foreign investments and become lucrative options for several global options as part of their global supply chains. These investments are more important in the current scenario as global firms are focusing on building resilient supply chains through redundancy and flexibility. Several global firms are considering different locations apart from the traditional Chinese mainland after several of their supply chains faced cascading disruptions after the COVID-19 pandemic. Therefore, the present study provided a decision-making framework to help the policymakers in the selection of sectors for prioritising investments. The sectors identified were pharmaceutical, chemical, apparel, agriculture and aquaculture. This study identified sectors based on their performance on technology, cost, flexibility, lead time and research. Since there are several alternatives amongst which one sector has to be selected, the sector selection becomes a multi-criteria decision-making problem. The problem was solved using Analytical Hierarchy Process (AHP). Based on the AHP model, the sector selected is the pharmaceutical sector followed by the chemical sector, agriculture and aquaculture. The apparel sector is given last priority as India largely depends on China for raw materials.

The results of the study imply that the pharmaceutical sector should be given priority in investments towards its development as it has shown the best performance while considering all the performance criteria of cost, flexibility, technology, lead time and research. This is also validated from the fact that during the pandemic the sector was greatly praised by WHO for its swiftness in providing life-saving medicines to the world. With the investments from the government and better development henceforth, the sector will be enhanced to not only perform advanced research but also provide more life-saving drugs to the world. The policy makers can select the sectors that have the top 3 priority weight for investment purposes as they fulfil majority of the performance criteria. Also, the results show that aquaculture and apparel sector are not fulfilling the performance criteria and hence the reasons should be looked into.

Although the study contributes towards introduction of a sector selection decision making framework, it takes only five major sectors having high potential. The results can be extended to more Indian sectors that are among the world leader in terms of their output, imports and exports. For model generalization purposes, further studies with respect to regional characteristics and types of conventions must be conducted and analysed.

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