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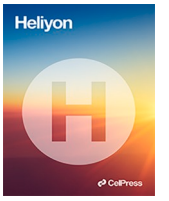

Barriers to Minimisation of agri-products wastage through Optimizing logistics in India: An ISM modelling approach

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ABSTRACT

The research work identifies and priorities the factors affecting agri-logistics causing wastage of the agricultural products during its transit from farm to the point of consumption so that logistics mechanism for agriculture sector in India can be optimised by removing the barriers leading to hindrances in safe, timely, economical and good condition delivery of the agri consignment. The field of agri-logistics remains at the crucial nexus of the agricultural and logistics industries and has the potential to improve the nation's system for distributing food. The post-harvest wastage in India has been massive due to inefficiencies agri-logistics management and faulty food distribution mechanism. It is an exploratory study that along the factors (barriers) identified and synthesised from literature review of the concerned area. The identified barriers were reduced and finalised in consultation with the experts using Delphi technique. With the help of ISM questionnaire, a model has been developed reflecting the drivers and dependents out of the barriers considered for the study. The result is further validated through MICMAC analysis. The result of the study has come up with the interpretive structure model depicting hierarchy of the barriers pushing from down to top causing agriculture wastage. The paper holds originality in the sense that it comes up with fresh perspectives on the factors causing hindrances in the efficient logistics operation that certainly helps to minimise wastage of the agri-products in the post-harvest stages. The identification of the barriers and their detriments to the other factors will help to take essential steps on how to overcome the issues and optimize the agri-logistics that would minimise the agri-wastage in India and prove to be a game changer to the agri-trade sector.

1. Introduction

Problem of food wastage in India has been an issue along with it enjoying the privilege of being recognized as global leader in production of several agricultural products. It has been estimated by Indian Council for Agriculture Research (ICAR) that, of the total food produced in India get wasted because of fragmented food system, lack of proper infrastructure and inefficient supply chain mechanism. If it comes to wastage of agri and food items, there is another estimation regarding wastage at home reflected by Food Waste Index 2021 revealing that approximately 50 kg of food gets wasted every year per person in India. It seeks the justification for how we need to consume food at home in logical manner to avoid wastage at home. This figure certainly indicates deplorable condition of food management in India leading to shortage of foods for many. There is need for food management at different levels along the

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Table 1
Factors Leading to Wastage based on the Literature Review.

Factors Leading to Wastage	Description	Authors (Year)
1. Inadequate cold chain storage	Horticulture and fresh vegetables need temperature-controlled storage infrastructure primarily at farm level and then at other stations to avoid any spoilage in quality that makes such produce get wasted.	[2–6]
2. Lack of rail/road connectivity	There is lack of proper and adequate connectivity between farm area and market which leads to the issue of market accessibility for farmers thus they fail to sell their agri-produce in time leads to wastage.	[2,4,6,7]
3. Lack of skilled manpower at farm level	The population engaged in farm activities in rural area are unskilled as they don't have or have minimal formal training or technical knowledge which leads to proper handling issues of food grains resulting in wastage.	[4–8]
4. Lack of trained personnel at different stage of logistics	There are huge number of unorganised logistic operators who are untrained and lack in professional skills therefore they fail to handle their responsibility at best to optimize the logistics operation.	[4,5,8]
5. Poor procurement	It refers to the disability of farmers in getting the right price for their produces due to unavailability of genuine purchaser. The involvement of unauthorized and unorganised market leads to poor procurement of the agri-produce leading to wastage.	[2,3,5]
6. Large number of Intermediaries (middlemen)	Due to lack of organized market and unavailability of genuine purchaser the farmers have to rely on middlemen who becomes a halt for the produce before reaching final consumer or factory in channel. As many middlemen involvement seeks repeated loading and unloading causing packaging and potential of wastage.	[3,4]
7. Lack of updated technology and instrument at farm level	Lack of modern technology and updated handling equipment and poor harvesting equipment lead to under processing of the agri-produce at farm level, due to which considerable amount get wasted.	[2,4,7,9,10]
8. Lack of storage facility	Lack of proper and adequate storage facility has been one of the prime reasons for huge food grains loss in India. It is required with proper connectivity with huge capacity and covered storage facility.	[2,3,6,7]
9. Lack of primary market or mandi facility	Due to a lack of primary market/local market the farmers are not able to sell their products which delays and leads to quality degradation.	[2,3,6]
10. Poor packaging	Poor packaging leads to wastage as packaging is meant to minimise wastage, protects from mechanical damages, and moister loss.	[5–7]
11. Lack of food processing units	The wastage of agri-produce can be minimised by diverting such produces to processing units that increases their self-life.	[3,5,6]
12. Lack of integrated logistics	The fragmented supply chain, too many intermediary causes disruption in efficient logistics operation and thus causing delay in transit leading to wastage of food grains and food articles.	[11]; Somashekhar et al. (2014) [4];
13. Poor processing at factory	Unskilled and absence of well-crafted processing mechanism at factory leads to non-optimal use of the agri-produce leading to wastage.	[5–7]
14. Delay at collection centre	The collection of agri-products before transit and after transit is a very significant aspect in agri-logistics. The delay causes loss of quality and nutrients in agricultural produce which losses its demand too.	[2,3,5];
15. Poor post-harvest handling of agri-produce	After harvest of the agri-produce it faces degradation issue quantity and quality wise when it goes to processing, meets spoilage, rodents etc. during course of entire logistics mechanism including loading and unloading repeatedly.	[2,7,12–16]
16. Lack of optimised agri-product safety and management	The optimisation of agri-produce management and safety (security) has been an issue at different stages of agri-logistics. Due to lack of optimisation wastage takes place at all stages by and large.	[17]; Gebbers and Adamchuk, (2010) [4,18];
17. Poor government policy and stringent law	Government policy and regulation plays a vital role in smooth procurement of agri-produce in time and at best price. Irrational decision or policy regulation leads to strikes and boycotts during which huge agricultural produce are wasted every year.	[19–22]
18. Uncertain climatic condition	Due to uncertain weather condition crops in farm area and grains at farm gate gets rotten which is also a big issue leading to agricultural wastage.	[7,14,21]
19. Poor demand forecasting & information	Forecasting regarding demand (information) plays vital role in agri-supply chain mechanism especially in case of perishable and shorter self-life goods. This leads to wastage because of poor planning and management of agri-product harvesting, packaging, storage, and distribution etc.	[23–26]
20. Lack of proper material handling	It is concerned with all the procedures involved in the movement of agricultural goods, whether they are in their raw state, processed state, or finished state. noted that this movement often covers a small distance. This movement may involve loading, unloading, packing, distributing, and other activities starting right from harvesting.	Coyle, (1992); Anderson, (1999) [27]; Wether et al. (2000)
21. Lack of Reefer container, and transportation facility	There are many agricultural products that need quick and temperature-controlled transportation mechanism due to lack of which quality of the agri-items in transit may get degraded leading to its wastage.	[22,28,29]
22. Fragmented marketing channel	Food grains are spoiling and deteriorating on large scale due to lack of integrated approach in the marketing channel causing hollow in information flow leading to inefficient agri freight flow.	[28,30,31]

need for bring change in the psychology of having willingness for *food abundance* to the mindset of *food scarcity* to have sustainable food and zero waste management approach (see Tables 7–13).

The latest data regarding post-harvest agriculture produce wastage released by ICAR, (2016) and Central Institute for Post-Harvest Engineering and Technology (CIPHET) which is quoted by Press Information Bureau (PIB) in 2020 revealed that the total annual wastage amounts for over Rs. 90,000 crores in value term. The average range of food loss in India ranges from 4.6 % to 15.8 % (ICAR, 2016). As per National Academy of Agricultural Science (NAAS, 2020) India had huge production of 291.95 million tonnes of cereals during 2019-20 of which around 6 % is lost due to poor storage mechanism. Not just storage, but these losses include wastage during harvest, collection, threshing, cleaning, drying, packaging, storage, and transportation which are all significant components in the food value chain [1].

Fruits and vegetables accounts for greater loss in percentage as revealed from Table 1 as it comes under perishable segment that is prone to mechanical and microbiological damages due to miss-handling or inadequate cold-storage infrastructure and modern warehouses at farm level.

***Complexities in Agri-Value Chain and causing Wastage*:** Several stakeholders are involved in agri logistics process which rely on transportation infrastructure, logistics service providers (Naik and Suresh, 2018). Fig. 1 presents the entire value chain along with the certain issues impeding efficiency of agri logistics and leading to wastage of agri produces.

It has also been found that, despite the huge storage/stock of food grains in warehouses the wastage continued due to poor distribution channel or unplanned government strategy. During covid hours in India, supply of food grains remains disrupted due to such reasons that caused mass people suffer and the grains got wasted. No accessibility of farmers to the market to sell their produces has been a common problem in India results in tonnes of food grain wastage in India. So, the synthetic of wastage of agri and food products in India are comprised of the mismanagement at various front be it at farm level, market level, storage level, transportation link, manufacturing unit or final stage of consumption [32]. also revealed that agricultural production gets wasted due to improper handling and storage, pest infestation, poor logistics, inadequate storage and lack of transportation infrastructure. Instinctive hoarding by unethical market players disrupts the agri and food value chain is also a critical issue in India.

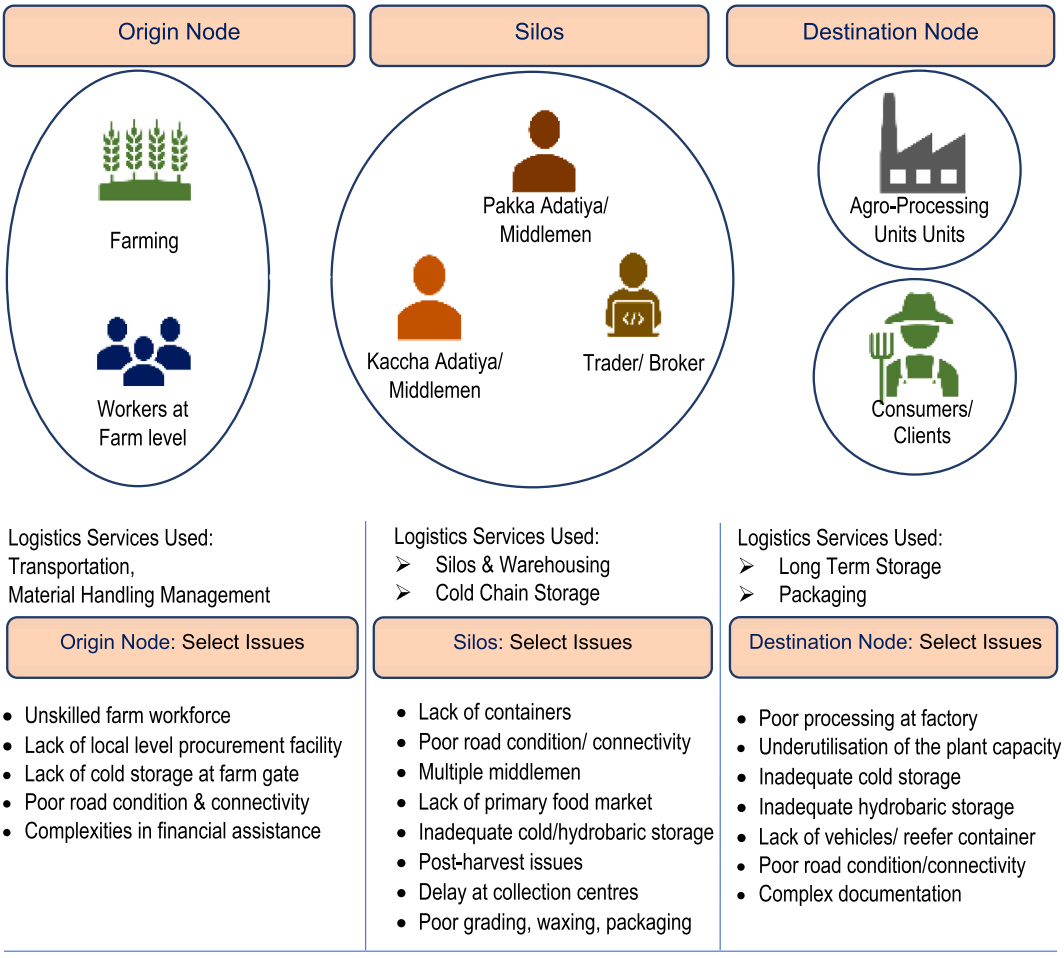

Fig. 1. Impediments at different levels of agri-logistics.

The government in India has taken initiatives to assist in strengthening the logistics infrastructure by allowing foreign investment and making investment through Pradhan Mantri Kisan Sampada Yojana (PMKSY) Schemes which tends to build mega food parks, cold chain storage, enhancing food processing and preservation capacities, backward forward linkages, processing clusters, food safety measures etc. but the problem of agri-produce wastage continues. Thus, there is a need for assessing the issues leading to food grains wastage at different levels i.e., from farm level, procurement, storage, transit and all which would boost the prospects of its growth in domestic and international markets as well.

Food loss and waste management in India requires a roadmap that is based on data-driven plans and solutions and takes into consideration the difficulties experienced by many stakeholders. Increased awareness and investigation of all facets of food loss and waste are required. A new multi-stakeholder activities network for sustainable food systems may stimulate cooperation and collaboration, focus the research agenda, mobilise action, and support policy and its implementation.

The study covers scanning of different disablers to the logistics operation in India and then narrowing them to the agri-logistics specific barriers causing wastage. The study covers perception and expertise of logistics professionals, academicians, and farmers at farm level to understand the appropriate disabling elements leading to inefficiency in logistics of food grains and fresh agri products including vegetable items. They have been considered as group of respondents and experts because farmers are the first stakeholders who actually face the real issues at farm level, agri-produce dedicated or dealing LSPs have better picture of the issues faced by them during the shipment, packaging, processing, loading, unloading, storage etc. of the agricultural products, and academician who were having 25 years of experience in teaching and research in supply chain and logistics who may have better analytical vision regarding the issues encountered during agri logistics leading to the wastage of agricultural produce.

1.1. Research Questions

1. What are the main factors causing wastage of agricultural produce in agri-logistics and supply chain in India?
2. Which barrier has greater magnitude in causing impediments to efficient logistics that leads to wastage of the agricultural products?
3. How can these issues be addressed to achieve efficient and smooth agricultural logistics which would help to minimise the agri-produce wastage in India?

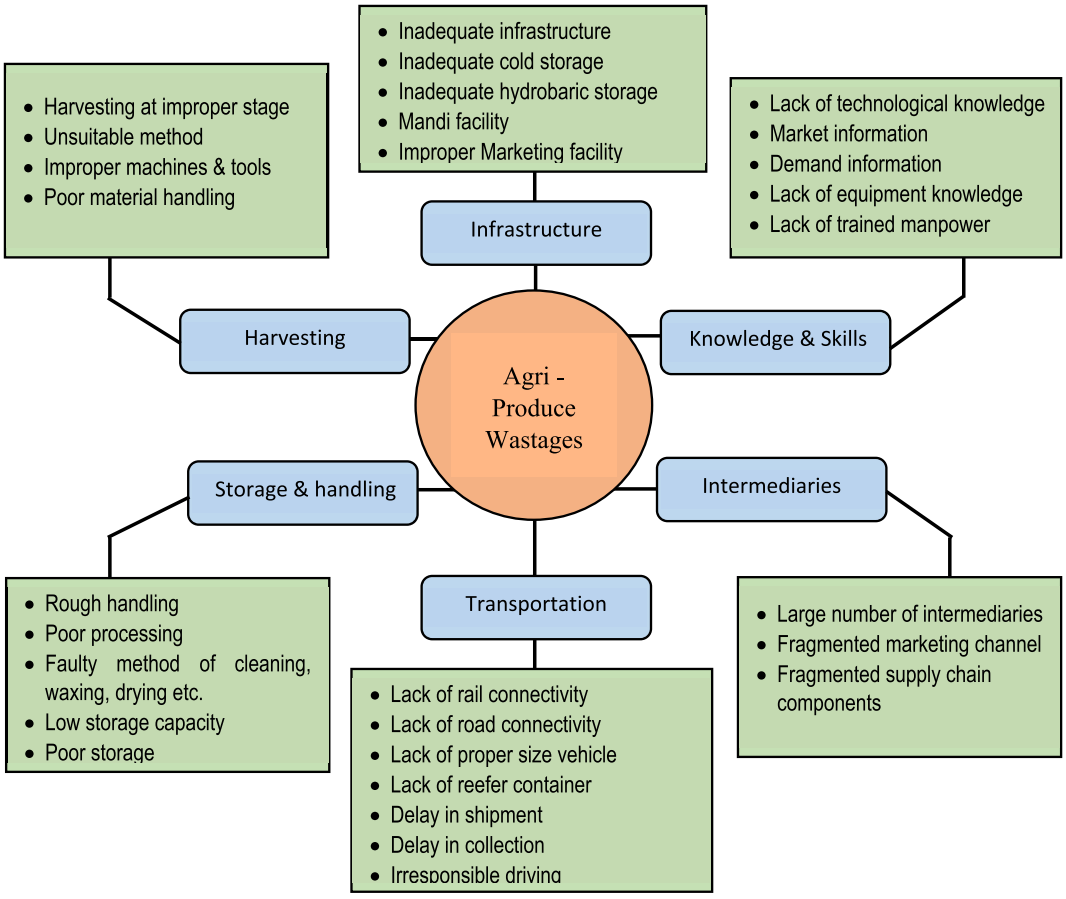

Fig. 2. Factors leading to losses and wastage in the supply chain.

1.2. Objectives of the study

1. The study aims at identification of the barriers creating hurdles in the efficient functioning of logistics operation pertaining to agricultural products from farm level to the customer end resulting in wastage of the agri-products.
2. The study examines the identified barriers finding out interaction among them to reveal how they influence each other ultimately leading to food wastage by developing a comprehensive hierarchical system model.

1.3. Literature survey

There have been a several studies conducted over the identification of issues and impediments to the logistics operation in Indian agricultural context [4,33–37]. The wastage starts right from the farm gate and continues till it reaches the final consumer [38]. [1,39] have mentioned that most of the wastage at farm-gate is due to adoption of faulty methods of cleaning, drying and storage by farmers. [33] recognizes storage issue as one of the prime reasons for wastage to a greater extent, because different food grain may require specific storage infrastructure.

Inventory and transportation management plays a very significant role in managing the food grains security and providing safety to fresh agricultural produces. Though there have been a few studies on inventory transportation issues in general but [40] revealed that there are very few studies relating to food grain transportation and distribution in Indian context. Beside this, there are several areas in agriculture supply chain and logistics mechanism such as poor infrastructure, lack of knowledge [4,5,8],intermediaries (Negi and Anand,2017; [4], transportation [2,4,6], and storage and handling [3,6]of the agri produce, which lead to the agri-produce wastage as have been presented in Fig. 2. The figure categorically reveals that the wastage of agricultural produce is possible at all levels in the agri supply chain.

[41] has mentioned that to have a positive influence on the agri-producers the efficient management of logistics operation becomes essential as it influences the storage, management of food articles and grains, cost competitiveness, and timely delivery which minimises the wastage of food grains. Infrastructural aspects are another significant area of concern on which the wastage of food grain depends a lot [42,43].

The studies [44,45]; Dudwick and Srinivasan, 2013; [46–48], re ports [49–51]; CIPHET, 2020) have revealed that Unskilled farm workforce, traditional approach of farming, lack of local level procurement facility, limited access to seed testing labs& seed certification agencies, lack of cold storage at farm gate, poor road condition & connectivity, complexities in financial assistance, inaccurate forecasting, poor procurement, lack of training and skill development programme for farmers and man power deployed at different stages in logistics operation, lack of containers, multiple middlemen, lack of primary food market at farm gate area, inadequate cold chain storage and hydrobaric storage, post-harvest management issues, poor grading, waxing and packaging, poor processing at factory, complex documentation causing delay, lack of proper size vehicle etc. are some of the critical issues which leads to wastage of food grains and other agricultural produces on greater scale.

There are too many intermediates, which causes the supply chain to be inefficient. There are many stakeholders operating alone, which prevents the ecosystem from becoming integrated.

The studies which have been examined have been enlisted in Table 1 reveals that the governmental, economic, and environmental factors of food loss and waste during course of agri-logistics remain mainly unexplored, therefore this study fosters the identification of those factors which are of this nature and thus, a total of 22 barriers have been identified from the literature review which reveals that these are the factors which impede the efficient and seamless logistics mechanism in the agricultural sector. But as the literature consulted shows that the study has not been conducted considering these barriers as reasons for the agri produce (fresh items, vegetables and food grains) wastages integrated in one study which provides scope for conducting the study. Considering the gap, present study has been undertaken to find out the factors leading to agri-produce wastage in Indian context.

Methodology: This section presents a comprehensive approach of methodology including research design, sampling method, data collection method, and analytical approach adopted to accomplish the study. It is an empirical study based on literature review, expert

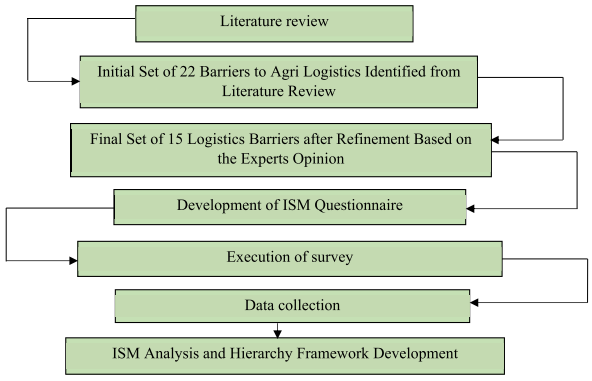

Fig. 3. Schematic presentation of research methodology framework.

opinion, and data collected through ISM questionnaire. The methodology adopted has been used by various research [52]; Anderson and Gerbing, 1988; Kelly and Vokurka, 1998). A total of 22 barriers were identified from more than 50 literature surveys including the studies conducted from 1973 to 2022. To conduct the study, a comprehensive methodology has been adopted as presented in Fig. 3.

Delphi Round for finalization of Barriers: For finalising the list of barriers causing impediments to the agri-logistics in India, a 2 round Delphi technique was used. In the *first round* of the Delphi technique, the list of total 22 identified barriers were placed before 18 experts which included professionals from 6 food processing units, 7 logistics service providers, and 5 academic professionals, who refined the list of barriers and suggested to merge few barriers into one. The experts were selected based on their vast experience of at least 15 years in their respective field. Professionals from the food processing sector and LSPs have better first-hand experience regarding the actual issues experienced by them during the course of logistics operation carrying agri-products. The academic professionals have been considered for the reason that, having 15 years of experience in teaching logistics and supply chain, have better understanding about the issues faced by agriculture logistics across the globe. The experts were found to have a common consensus over merging several barriers into one. Consequently, two new barriers were formed on their suggestion by merging different barriers, the first one was suggested to merge Inadequate Cold chain storage, Lack of storage facility and Poor storage into one as 'Lack of proper storage facility'; and the second one was to merge Poor material handling and post-harvest handling of agri-produce into one as 'Poor material handling at farm level and during logistics'. Also, four other barriers viz. Uncertain climatic condition, poor demand forecasting and information, lack of food processing units, and Poor procurement were eliminated from the comprehensive list of barriers causing agri-product wastage during agri-produce trade. Consequently, the list of barriers was reduced to 15 which are most relevant causing wastage of agriculture produce during agricultural logistics and supply chain in India. During the second round of the Delphi round based expert opinion, the experts were provided with the finalised list of 15 barriers with their definitions, for seeking their common consensus.

***Research Design*:** It is an empirical study based on literature review, expert opinion through Delphi technique, and data collected through ISM questionnaire a proven methodology for developing hierarchy model used by many researchers [52]; Kelly and Vokurka, 1998).

***Sample Size*:** The study has conducted along 29 responses and found to be enough for the analysis because many studies (Rangtusantham, 1998; Fozra and Filippini, 1998 [53]; confirm the expert opinions for minimum 15 experts are acceptable. Considering the same, 24 experts were taken into consideration for collecting the responses and conducting the study based on that. The experts (respondents) were selected based on their expertise in their respective fields with more than 10 years of experience.

***Data Collection*:** Along the finalised barriers (Table 2), ISM questionnaire was prepared with 15 barriers in bidirectional mode i.e., *i* and *j* vertically and horizontally to provide information by putting V, O and X to explain the mutual and directional relation among the barriers. 24 questionnaires were distributed among the LSPs, food processing units, and freight forwarders. Also 16 responses were collected from farmers adopting scheduling method, and a total of 40 responses were collected. The responses were collected from three different response base to avoid respondent bias considering them as having better angle of understanding the issues faced at farm level, at the shipment stage and from the viewpoint of academic analyst who possess their expertise and visibility on both the farm level issues and during the logistics operation. The responses were collected with their consent to use it for the study. The collected data sheet was examined and validated by the experts and based on their validation 29 responses have been found suitable for the analysis and study. Along the collected data, Interpretive Structural Modelling technique has been used to model the factors causing agricultural produce wastage in India.

***Analytical Approach*:** The study has been conducted Interpretive Structural Modelling Technique and thereafter MICMAC analysis has been conducted to validate the driving and dependance power of the barriers and finding their spot. The ISM analysis has been conducted with ISM-Win (2015) developed by John N. Warfield. Further, MICMAC approach is applied to validate the results of ISM approach.

***Interpretive Structural Modelling (ISM) Approach*:** Warfield, (1994) revealed that ISM presents a structure of the variables which are describes the connections among the variables to each other, and in this study the same has been adopted to evaluate the agri-logistics barriers relevant to cause food grain wastage and wastage of other agri-products as well. It is multi-criteria decision-making methods (MCDM) approach that provides order and direction for numerous complex relationships among the variables (Singh et al., 2003; [54]. Because the group of the experts judge how the various elements (enablers or disablers) are related, this process is interpretive. It is structural on the premise of interdependence; an overall structure is derived from the intricate collection of components, and considered as modeling tool since a digraph layout depicts the precise relationships and general hierarchy. It aids in imposing a framework and structure on the complex relationships between different system elements [55,56]. ISM, or interpretive

Table 2
Coding of the selected barriers.

Barriers	Code	Barriers	Code
Lack of optimised agri-product safety & management	B1	Lack of reefer container and transportation facility	B9
Poor Processing at Factory	B2	Lack of proper storage (poor storage and lack of cold storage also)	B10
Poor Packaging	B3	Poor post-harvest handling of agri-products	B11
Lack of primary market mandi facility	B4	Lack of transport connectivity and transport infrastructure	B12
Large number of middlemen	B5	Lack of trained personnel at different levels of logistics	B13
Delay in collection at collection centre	B6	Lack of updated technology and instrument at farm level	B14
Lack of integrated logistics	B7	Poor government policy and stringent law	B15
Lack of skilled manpower at farm level	B8		

structural modeling, is a well-known technique for determining connections between particular elements that characterise a problem or issue. There may be several aspects that are connected to an issue or problem for every complex situation under discussion. The situation is described far more correctly by the direct as well as indirect association between the elements than by any one aspect considered separately. ISM thus generates insights into general perceptions of these linkages. The model judges consensually the relationship among the different barriers causing hindrance in the logistics of agriculture product that tends to minimise the wastage. A total of 15 barriers have been taken into consideration out of 22 identified from comprehensive assessment of the literature pertaining to agriculture product wastage based on the experts' opinion.

Steps involved in the ISM Approach: The model development has been done along the following different steps involved in interpretive structural modelling. The resulting model depicts an intricate issue or problem's structure in a well-planned layout that suggests both visuals and words..

Step 1. Barriers causing impediments in agri-logistics are listed, and they can be of Objectives, Actions, and Individual nature etc.

Step 2. Establishment of the contextual relationship among the identified variables based on the responses received from the respondents along which pairs of variables would be examined.

Step 3. Development of Structural Self-Interaction Matrix (SSIM) for variables, indicating pairwise relationships among variables of the system under consideration.

Step 4. Development of Reachability matrix from the SSIM and examination of the matrix for tracing out any existence of transitivity which is basic assumption made in the model. (The transitivity indicates the mutual relation between the variables in hierarchical form for instance if B1 is associated with B2 and B2 is associated with B3 then it is assumed that B1 is related with B3.

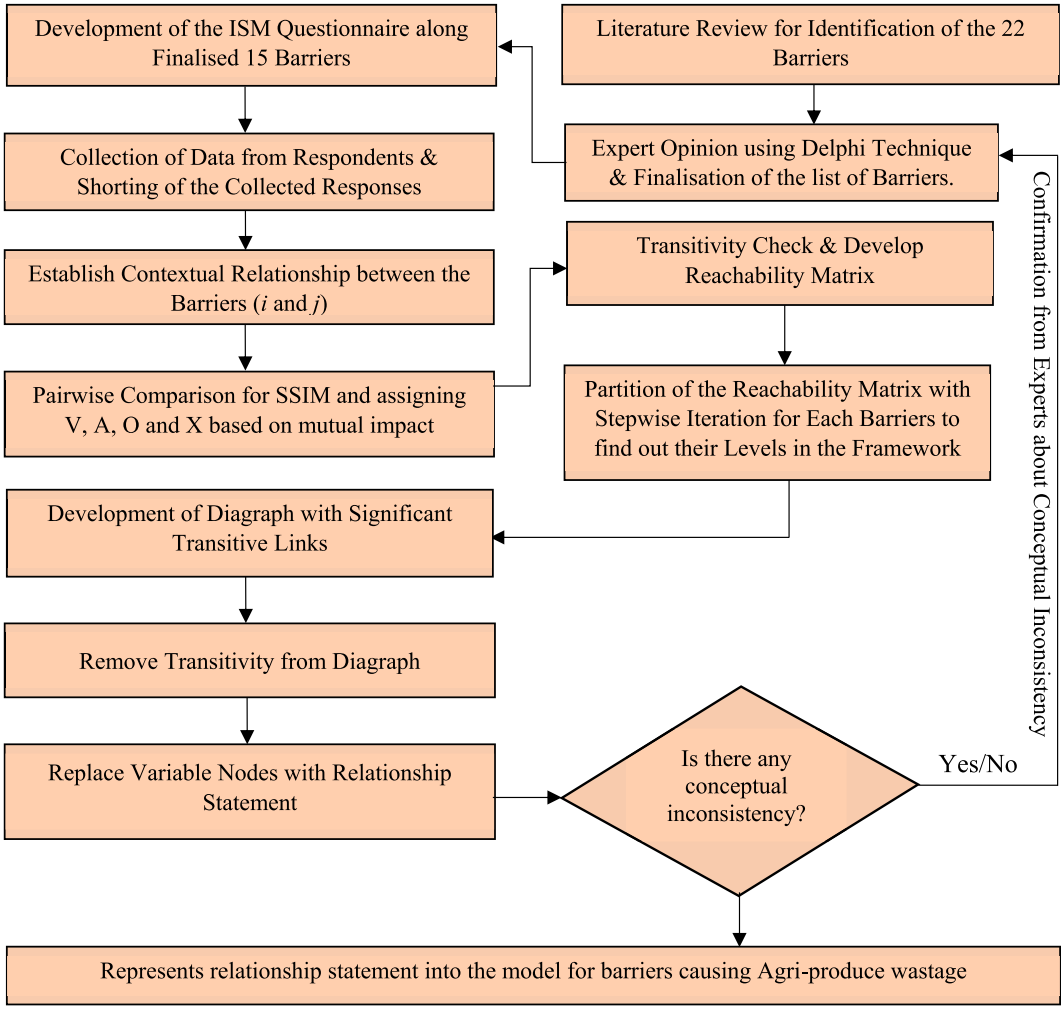

Fig. 4. Flow diagram of ISM methodology.
[Source: Modified from Jain and Raj, (2015)]

Step 5. Partitioning of the Reachability matrix obtained into different levels.

Step 6. Development of diagraph with transitive links based on the levels of placement of all the barriers.

Step 7. The resultant digraph is converted into an ISM hierarchical framework, by replacing variable nodes.

Step 8. The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

The ISM methodology adopted in this study has been presented through a flow diagram in Fig. 4.

Fig. 4 shows the systematic flow in which the ISM analysis has been conducted and finally the hierarchy framework has been developed. Based on the driving and dependence power acquired from development of the reachability matrix in ISM modelling, the barriers were further put to MICMAC analysis validating the intensity of influence factors are having on each other mutually.

1.4. MICMAC method

Matrice d'Impacts Croises-Multiplication is known as MICMAC. Apply a Classment (classification-focused cross-impact matrix multiplication). The MICMAC approach is based on matrices' multiplication characteristics and is done to pinpoint the primary driving forces behind the system across different domains. The factors are divided into four groups based on their driving and dependence powers: autonomous, linkage, dependent, and independent factors (Mandal and Deshmukh, 1994; Sharma et al., 1995).

Autonomous variables: These components lack motivation and dependability. They have limited linkages to the system, which they are somewhat isolated from, but those elements may have extremely strong existence in the system.

Linkage factors: These factors possess strong driving and dependence power and are unstable in nature that any action will result in having significant influence on other factors and a knock-on effect on themselves.

Dependent factors: These factors have weak drive power but strong dependence power.

Independent factors: These factors have strong drive power but weak dependence power. The term "key factor" refers to a factor with a particularly potent driving force that belongs to the independent or linked factor group.

1.5. ISM analysis

Step 1: *Identification of the barriers to the minimisation of agri product wastage*– The risks causing hurdles and inefficiency in implementation of PPP model have been identified by literature review and, and expert opinion from the railway officials.

Step 2: *Development of Contextual Relation* – The contextual relationship may be '*i* influences *j*' or '*j* influences *i*'.

Step 3: *Pairwise Comparison for SSIM* – Keeping in mind the contextual relationship for each variable, the existence of a relation between any two barriers (*i* and *j*) and the associated direction of the relation is questioned. Four symbols have been used to denote the direction of relationship between the barriers as have been depicted in the SSIM in Table 3 (where *i* presented in column and *j* presented in row):

V: Barrier *i* affects Barrier *j* (Barrier j can be alleviated by improvement of barrier *i*);

A: Barrier *j* affects Barrier *i*; (Barrier *i* can be alleviated by improvement of barrier *j*);

X: Barriers *i* and *j* influence each other; and.

O: Barriers *i* and *j* are unrelated.

Step 4: *Reachability Matrix* – The SSIM is restructured into the binary matrix, which is also known as initial reachability matrix. The transformation is done by substituting V, A, X, O with 1 and 0 as per the case under the stated rule as have been stated below.

1. If the (*i*, *j*) entry in the SSIM is V, then the (*i*,*j*) entry in the reachability matrix becomes 1 and the (*j*, *i*) entry becomes 0.
2. If the (*i*, *j*) entry in the SSIM is X, then the (*i*,*j*) entry in the reachability matrix becomes 1 and the (*j*, *i*) entry also becomes 1.
3. If the (*i*, *j*) entry in the SSIM is A, then the (*i*,*j*) entry in the reachability matrix becomes 0 and the (*j*, *i*) entry becomes 1.

Table 3
Structural Self-interaction matrix (SSIM).

Barriers	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2
B1	A	A	A	A	A	A	A	O	A	A	A	O	A	A
B2	A	A	V	A	V	A	A	A	V	A	V	A	X	–
B3	A	A	V	A	V	A	A	A	V	A	V	A	–	
B4	O	A	V	V	O	X	V	O	V	V	V	–		
B5	A	X	V	X	O	X	V	O	O	A	–			
B6	A	A	V	A	V	A	A	A	V	–				
B7	X	A	A	A	A	A	A	A	–					
B8	X	V	X	V	V	V	V	–						
B9	O	A	V	A	V	A	–							
B10	A	A	V	A	V	–								
B11	A	A	A	X	–									
B12	A	X	O	–										
B13	A	A	–											
B14	A	–												
B15	–													

Table 4
Final reachability matrix.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	Driving Power	Rank
B1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	XI
B2	1	1	1	0	1	0	1	0	0	0	1	0	1	0	0	7	VII
B3	1	1	1	0	1	0	1	0	0	0	1	0	1	0	0	7	VII
B4	0	1	1	1	1	1	1	0	1	1	0	1	1	0	0	10	IV
B5	1	0	0	0	1	0	0	0	0	0	1	0	1	1	0	5	VIII
B6	1	1	1	0	1	1	1	0	0	0	1	0	1	0	0	8	VI
B7	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	3	X
B8	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	13	I
B9	1	1	1	0	1	1	1	0	1	0	1	0	1	0	0	9	V
B10	1	1	1	1	1	1	1	0	1	1	1	0	1	0	0	11	IV
B11	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	4	IX
B12	1	1	1	0	1	1	1	0	1	1	1	1	0	1	0	11	III
B13	1	0	0	0	0	0	1	1	0	0	1	0	1	0	0	5	VIII
B14	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	12	II
B15	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	13	I
Dependence Power	13	10	10	3	11	8	13	3	6	6	12	6	10	5	2		
Rank	I	III	III	VII	IV	IV	I	VII	V	V	II	V	III	VI	VIII		

4. If the (*i*, *j*) item in the SSIM is O, the reachability matrix for both (*i*, *j*) and (*j*, *i*) entries become 0.

The transitivity listed in Step 4 of the ISM technique is added to create the final reachability matrix. In Table 4, this is displayed. The driving force and dependence of each barrier are also displayed in this table. In the MICMAC study, the barriers have been categorised into four groups: autonomous, dependent, linkage, and independent (driver) barriers.

Step 5: *Level Partition* – Level partition in TISM is carried out in similar way as is done in case of ISM, thus here also, the reachability and antecedent set [55] for each barrier is found out from final reachability matrix (Table 4).

As illustrated in Table 5 to Table 15, the final reachability matrix has been divided into various levels and the intersection set is derived from the reachability set and the antecedent set (see Table 14). The barriers that have identical values for both sets are at the top of the ISM hierarchy. Table 5 demonstrates that at level I stands Lack of Optimised Agri-Product Safety & Management (Barrier 1). In the ISM model, it would therefore be at the top. The levels of each variable are determined by repeating this process. Consequently, based on the level partition along the repeat process up to iteration 11 all the barriers have found their level of placement in the diagraph. In the next step iteration result based diagraph has been developed with the transitive links (see Table 6).

Step 6: *Development of Diagraph with transitive links*: The identified levels help in building the digraph and the final model of ISM. The diagraph is obtained from partition level and the conical matrix removing the transitive links as shown in Fig. 5. It clearly shows that lack of skilled manpower at farm level and poor government policy have come out as very significant barrier in causing wastage of agricultural produce in India as it comes as the base of the ISM hierarchy.

2. Results and discussion

Based on the entire steps followed in the ISM technique and development of the diagraph as presented in Fig. 5 under step 7, a barriers' heirarchical framework has been finally developed considering interpretive matrix as presented in Fig. 6.

Step 7: *Interpretive Structural Model Development* – It shows that the barriers at all levels possess crucial impact over some other and ultimately having leading influence on lack of appropriate agri-logistics performance matrix.

The lack of optimised agri-product safety and management on which the effectiveness of the agri-logistics and minimisation of agri-wastage depends has appeared at the top of the hierarchy. The poor government policy and lack of skilled manpower at farm level have emerged at the bottom of the hierarchy showing that they lead to the lack of the use of updated technology and instrument at farm level because the poor policy and execution by the government keeps the farmers and workers away from the use of technical equipment during pre-post-harvest stage of the agriculture produce. Further, lack of transportation connectivity and updated infrastructure has been placed at third level as significant factor leading to the agricultural wastage, and then it has been found that unavailability of primary market mandi in abundant and lack of appropriate storage facilities for the agri-products at different stages including poor storage capacity and lack of cold storage facility have been largely resulting to the wastage of the agricultural produce. Lack of reefer container and transportation facilities for transportation of agri-products at farm area, mandi region and primary processing area has been one of the issues before maintaining the quality of agricultural produce. The unavailability of the reefer container, in-abundance of mandi or its less capacity near farm area, inefficient transportation facility and poor connectivity causes delay in several activities involved, and thus, delay in collection of the agri-product by food processing units, agri-logistics operators and agri-based manufacturing units takes place. When the firm fails to collect agri-articles in time the other connected activities are affected. Delay in collection of the agri-produce at farm level ultimately affects the activities performed by the firms specifically processing of agri-produce and packaging of the processed food gets affected as lead time influences the processing and packaging mechanism. Not only this, but involvement of the large number of middlemen has been a characteristic in the supply chain and logistics mechanism of agri-products which requires repeated loading-unloading and opening and closing of the agriculture consignment causes disturbance in the logistics process efficiency.

Lack of trained personnel at different levels in logistics has been identified as the next significant factor causing wastage of food

Table 5
Partitioning the final reachability matrix (iteration 1).

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
1	1	1,2,3,4,5,6,7,9,10,11,12,13,14,15	1	I
2	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
3	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
5	1,5,11,13,14	2,3,4,5,6,8,9,10,12,14,15	5,14	
6	1,2,3,5,6,7,11,13	4,6,8,9,10,12,14,15	6	
7	1,7,15	2,3,4,6,7,8,9,10,11,12,13,14,15	7,15	
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
11	1,7,11,12	2,3,5,6,8,9,10,11,12,13,14,15	11,14	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
13	1,7,8,11,13	2,3,4,5,6,8,9,10,13,14,15	8,13	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 6
Iteration 2.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
2	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
3	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
5	1,5,11,13,14	2,3,4,5,6,8,9,10,12,14,15	5,14	
6	1,2,3,5,6,7,11,13	4,6,8,9,10,12,14,15	6	
7	1,7,15	2,3,4,6,7,8,9,10,11,12,13,14,15	7,15	II
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
11	1,7,11,12	2,3,5,6,8,9,10,11,12,13,14,15	11,14	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
13	1,7,8,11,13	2,3,4,5,6,8,9,10,13,14,15	8,13	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 7
Iteration 3.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
2	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
3	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
5	1,5,11,13,14	2,3,4,5,6,8,9,10,12,14,15	5,14	
6	1,2,3,5,6,7,11,13	4,6,8,9,10,12,14,15	6	
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
11	1,7,11,12	2,3,5,6,8,9,10,11,12,13,14,15	11,14	III
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
13	1,7,8,11,13	2,3,4,5,6,8,9,10,13,14,15	8,13	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 8
Iteration 4.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
2	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
3	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
5	1,5,11,13,14	2,3,4,5,6,8,9,10,12,14,15	5,14	IV
6	1,2,3,5,6,7,11,13	4,6,8,9,10,12,14,15	6	
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
13	1,7,8,11,13	2,3,4,5,6,8,9,10,13,14,15	8,13	IV
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

grains and agri-products as they fail to handle the agri-consignment right from the picking from farm level to the factory and then forward till it reaches the consumer, thus leading to wastage. Fragmented logistics has been one of the problems of Indian logistics [32], due to which cost and time incurred increases on the one hand and the quality and condition of the product diminishes on the other side. As integrated logistics ensures cohesiveness and alignment of all the elements involved in the mechanism, it enhances safety, security, performance, timely delivery, rules out unnecessary cost and thus increases logistics efficiency. Lack of optimised agri-product safety and management has been placed at the top of the hierarchy in the ISM model which indicates that safety and management of agricultural produces from farm to factory and then that of the agricultural produces and products from factory to the consumption location. All the barriers placed at the lower lever in the hierarchy influence safety and management of agri-logistics. Alleviation of all these barriers would lead to having a good agri-logistics system which would bring down the wastage level.

MICMAC Analysis: Analysing the driving power and dependent power of the variables is the goal of the MICMAC study (Mandal and Deshmukh, 1994; Sharma et al., 1995). As illustrated in Fig. 7, the variables are divided into four clusters and displayed along the X axis, which represents driving force, and the Y axis, which represents dependency. The autonomous barriers in the first cluster have

Table 9
Iteration 5.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
2	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	V
3	1,2,3,5,7,11,13	2,3,4,6,8,9,10,12,14,15	2,3	V
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
6	1,2,3,5,6,7,11,13	4,6,8,9,10,12,14,15	6	
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 10
Iteration 6.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
6	1,2,3,5,6,7,11,13	4,6,8,9,10,12,14,15	6	VI
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 11
Iteration 7.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
9	1,2,3,5,6,7,9,11,13	4,8,9,10,12,14	9	VII
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 12
Iteration 8.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
4	2,3,4,5,6,7,9,10,12,13	4,10,12,14	4,10,12	VIII
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
10	1,2,3,4,5,6,7, 9,10,11,13	4,8,10,12,14,15	4,10	VIII
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 13
Iteration 9.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
12	1,2,3, 5,6,7,9,10,11,12	4,8,11,12,14,15	4,11,12	IX
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

low driver power and low reliance. These barriers have limited, potentially significant linkages with the system, with which they are relatively cut off. The dependent barriers in the second cluster have a substantial reliance but a modest driving power. The third cluster contains linking barriers that are unstable by nature, with substantial driving and dependent forces. The independent barriers with

Table 14
Iteration 10.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	
14	1,2,3,5,6,7, 9,10,11,12,13,14	5,8,14,15	5,14	X
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	

Table 15
Iteration 11.

Barrier	Reachability Set	Antecedent set Intersect	Intersection set	Level
8	2,3,5,6,7,8,9,10,11,12,13,14,15	8,13,15	8,13,15	XI
15	1,2,3,5,6,7,8,10,11,12,13,14,15	7,8,13,15	7,8,13,15	XI

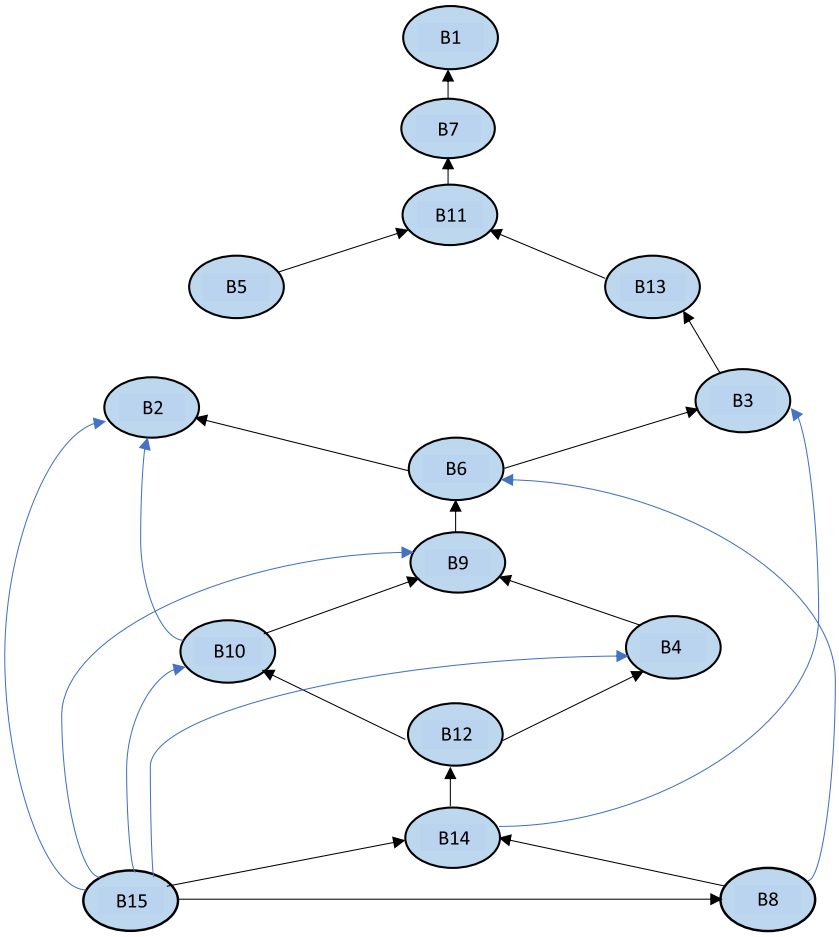

Fig. 5. Structural and hierarchical diagraph of barriers to logistics in agriculture sector.

great driving strength but constrained dependence have been placed in the fourth division. Analysis therefore tends to be the rich source of information based on driving power and dependence tendency of the barriers which critically define the scope of each barrier.

The analysis indicates that in case of agri logistics poor government policy, lack of knowledge and skill at farm level, transport connectivity, transport infrastructure, primary market mandi facility, different types of storage facility, reefer container are the barriers which have high driving power which causes agri-produce wastage itself with less dependence traits and pushing other factors to cause wastage as well which are highly dependent on these driving forces somehow. The factors having strong dependence character are delay in collection at collection center, poor packaging, poor processing, lack of trained personnels at different levels in logistics

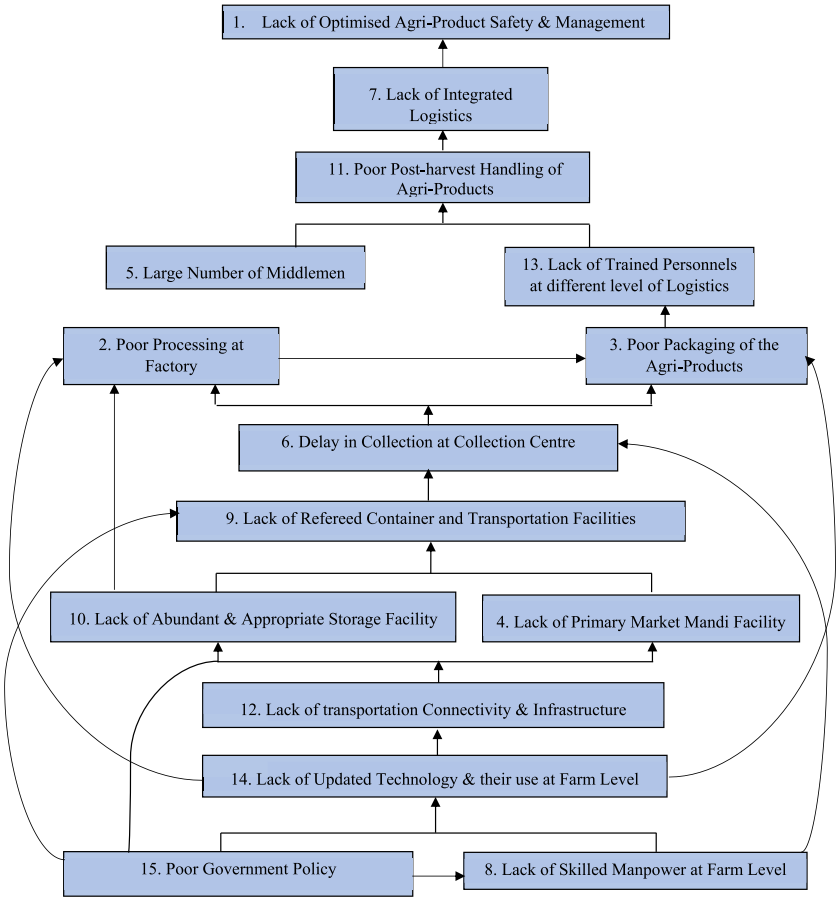

Fig. 6. ISM-based model for barriers to agri-logistics Optimisation.

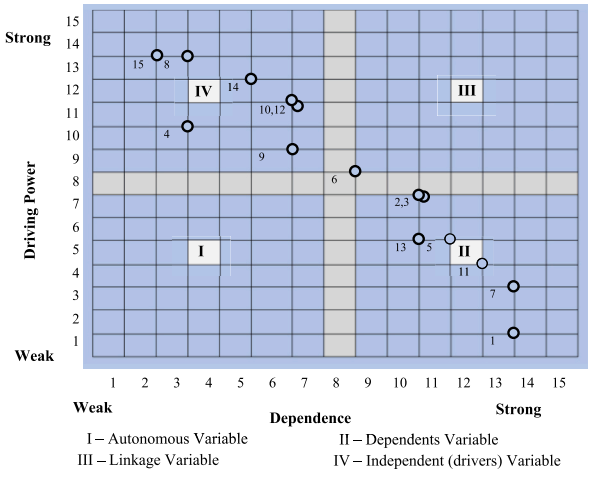

Fig. 7. Driving power and dependence diagram (MICMAC analysis).

operation, poor post-harvest handling of agri-produces, lack of integrated logistics, and lack of optimised agri-product safety and management. If the driving forces are.

3. Implication

The study provides fresh perspective on the order of the barriers affecting agri-logistics leading to the wastage of the agri-products, which enhances comprehension of the issue. An original addition to the field of agri-logistics is the prioritisation of the factors. The study can be useful from several perspective, specifically from viewpoint of government authorities and policy makers, infrastructure development authorities, logistics practitioners and researchers. The study recognizes managerial, government policy and academic implication as have been mentioned below.

Managerial Implication: The research findings offer useful information to supply chain professionals working in the agri logistics and food processing industry. Since they are the highest level hurdles, managers must concentrate on crisis-oriented management and coordination complexity. Managers therefore need to concentrate on innovation and modern technologies; upper management budget approval is also crucial. The food processing industry will be able to create SSCM networks if these major restrictions are removed. Additionally, social and environmental factors must be taken into account while establishing the network and deciding on location strategy while taking both long- and short-term strategies into account. To supply fresh goods to end users, reduce logistical costs, and increase profitability, food processing plants should be situated close to agricultural hubs and equipped with contemporary equipment.

The study reveals the area of concern which have high driving power and most of them are associated with the government policy as they are lack of mandi facility, poor government policy, untrainned and unskilled man-power at farm level, lack of proper connectivity and transportation infrastruture. All these can be resolved by the government authority. The government should conduct ground study through project to find out the region which are having high productivity but are less prosperous in having prompt transportation and connectivity, unskilled work forces in logistics and at farm level, less availability of material handling equipment, less storage facilities, and lack in mandi facility where producers can offer their produces for sell and supply. This would enable the government to take appropriate steps towards strengthening the sectoral performance from logistics point of view and would help in minimising the agriculture product wastage.

Academic Implication: The study identifies and examines those factors which are responsible for creating problems in efficient agri-logistics operation from farm to consumption point and leading to the agricultural wastage. The identified barriers can be considered for other sectoral logistics assessment. The literature which have been considered in the study can be utilised for further studies, and the model developed showing driving and dependence factors may be used for predefining them for categorical studies.

Relevance to the Stakeholders: The out come of the study depicted through hierarchy modekl and driving and dependence power based placement of the barriers clearly indicates the priority based need for solution of the issues that may tend to have respective influence on the other barriers. As the agri-logistics mechanism in this study has considered farmers, policy makers, and LSPs as the main stakeholders, the study provides scope for taking up solutionary measures for these all. It is being suggested that skill development, extension and building up of mandi facility, modern day machinery use at farm area, storage facility all these at farm level may enhance the efficiency of logistics operation and thus would bring down the wastage that takes place at farm level. The policy makers may pay their attention towards mandating for training and skill development programme for not just farmers but for all the man power engaged at different levels in the logistics and supply chain of agri-products so that they can better handle the agricultural goods and consignment, infrastructure development mechanism (including setting up of storage and warehouses, collection centres, more transportation facilities, dedicated transportation corridore, more container stations, custom houses and their operation, port infrastructure, uninterrupted power supply etc.). The LSPs can hire more trained personnels, may organise or take part in the training and skill development programmes, may adopt better transportation facilities ensuring better safety and material halding.

4. Conclusion

The ISM framework clearly reveals that poor government policy, lack of skill at farm level, lack of technology and equpment, connectivity, unavailability of primary market, and poor logistics transport infrastructure are the major cause of agri-procut wastage in India and are confirmed through MICMAC analysis that indicates these are the highly capable of influencing other factors to cause wastage of food grains and vegetable items during logistics. The unorganised collecten centre, lack of appropriate storage and warehousing, procedural delay at different touch point (collection centre, custom clearance, port processing), packaging issue, poor processing are the other significant issues which are highly influenced by the highly driving power having set of barriers and thus have higher dependence.

The study conducted along the identified barriers to the agri-logistics reveals that the unskilled farmers to handle the pre and post harvesting of agri product has been one of the significant aspects leading to the agricultural wastage at primary stage. A lot depends on the governemnt policy regarding infrastructure installation at different levels. At farm level government efforts for the financial adds, imparting skill and training to farmers, supporting prices to the farmers, primary level market mandi near farm location, better transport connectivity and healthy transport infrastructure and many as such may play crucial role in reducing losses during harvesting, threshing, sorting and grading of produce. Other than this, government policy and steps for strengthening the agri-logistics infrastructure such as warehouses and cold storage set-up, transportation infrastructure, container availability, collection centre, training for logistics professionals etc. have been crucial in emparting efficiency to overall agricultural logistics and trade, which may help to reduce loss of food grains and fresh vegetable items specially. Losses of food grains and other fresh agri produces in the agriculture supply chain can be decreased by educating farmers with specific skill sets to handle the specific tasks about better

harvesting techniques, enhancing aggregation through FPOs, and shortening the time between harvest and sale of produce.

The government policy becomes quite significant in establishing a prosperous environment for encouraging the growth of agricultural sector and minimising the wastage. If there will be healthy government policies regarding strengthening the skill set of farmers and logistics professionals, financial capacity of the farmers, and better agri-logistics infrastructure building then there is large probability that the country may overcome barriers like procedural weaknesses, poor material handling, poor shipment, fragmented logistics, and poor storage of the agri items.

Based on the discussion with the experts after reaching the infderence of the study it was concluded that private investors may prove to be boon in setting up the agri-trade and logistics infrastructure and setting up of conginial environment in the country within the general framework of a favourable climate given by the government side. The managerial improvements made to the agricultural economy of the nation by the private sector would significantly improve resource utilisation, assuring sustained growth for the industry.

5. Limitations

Despite the fact that ISM technique is a well defined model, there are certain drawback as the relationships between the variables constantly depend on the respondent's expertise and experience with the specific business unit and its operations, consequently the model created may be substantially impacted by the respondent's bias. The study has been conducted based on the responses collected from food processors, agri-logistics service providers and academician who may not be able to reflect the exact problems faced by producers at farm level leading to wastage, therefore it is suggested that the future study may be conducted by clearly defining the pre harvest challenges and post harvest challenges leading to agri produce wastage. Also the LSPs included in the study are not just limited to deal in agricultural produce but also dealing in general consignment, that may have affected there response regarding accuracy of a barrier and their responses regarding its validity. The study has region based potential bias as it has been conducted along response from the experts from central part of India including Uttar Pradesh, Delhi, Maharashtra, Haryana and Hyderabad region, and the other parts of the country have not been considered for data collection. The rationale for limiting the region for data collection was these regions being dominant in agricultural production. The geographical conditions plays vital role in logistics operationand may cause great difference when other part of the country is considered, so the result may not be the same if other geographical regions are considered for the purpose.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Sameer Shekhar: Formal analysis, Data curation, Investigation, Methodology, Writing - original draft. **Rubee Singh:** Supervision, Conceptualization, Project administration, Writing - review & editing. **Shahbaz Khan:** Conceptualization, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e21551.

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