AHP-TOPSIS Based Multi Criteria Decision Making (MCDM) Approach for Performance Evaluation of Commercial Food Grain Storage Practices in Indian

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Abstract

Food grains are an important part of the Indian diet. The grain production has been steadily increasing over the years with advancement in scientific productions. The produced grains are being most commonly stored in bag storage in go-downs/warehouses and cover and plinth storage (CAP), silos, and various other methods like conventional storage structures etc., to maintain grain quality characteristics for certain period. Due to improper storage practices are resulting in huge losses of the total production of the country. World Bank, have reported post harvest loss of 10% to 16% of food grains every year in India, which impedes the mission of achieving food security in India. In parts, among the major causes of these losses are the reluctance among farmers, especially of small holding, towards adoption of scientific storage methods/ technologies and inability of the national agencies to meet the challenges imposed by the supply of surplus grains to them by the farmers. Although sets of improved grain storage technologies exist among Indian farming communities, a controversial account about their effectiveness and performance is available in the literature which negatively impacts the endeavor of bringing rapid developmental in the farming associate societies. In order to develop an informative argument about the performance of the existing storage practices, a nearly comprehensive study has been undertaken to compare the different commercial food grain storage structures used by Indians. Both qualitative and quantitative parameters were compared individually and simultaneously to achieve their effect on performance individually and in unison. Another objective of the study was to test the applicability of hybrid and multi-attribute approach, based on Analytic Hierarchy Process

(AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for the performance evaluation and ranking of the attributes and structures. Finally, based on analysis and ideas borrowed out of literature a set of theoretical and conceptual guidelines to assist improvement in these structures was brought in. The study will help understand the status of grain storage practices in the society and also increase the adoption of better storage practices.

Keywords: Grain Storage, Seed Storage, Handling, AHP-TOPSIS, Multi criteria decision making, Ranking, Silo, CAP, Go-down

Introduction

The food is the symbol of life and prosperity. Food grains comprising of cereals, millets and pulses, forms the primary and staple food of majority of the population in India. The introduction of high yielding varieties in the early sixties which has ultimately blossomed in to Green Revolution has helped India, to emerge as one of the leading developing country in the front of agricultural economy resulting in increased food grain production, touching more than 259 million tone in the year 2020-21. However, in India, during past few decades, a nationwide inadequacy in preventing and reducing post-harvest losses of stored grains or seeds have been reported (Mishra et al. 2012, Nagpal and Kumar 2012). While grain is the major source of food, seed is the basic input of agriculture to keep the food production system alive. Grain as well as seed productions follow a long chain of agronomic activities followed by biological processes in the plants and thereafter human intervention for its processing, storage and distribution (Maity and Pramanik 2013, Maity and Chakrabarty 2013). If any of the steps is exposed to adverse weather conditions they lose their value and sometimes they become unusable (Maity et al. 2016)

According to the government reports available from 2010 to 2020, about 17,423 tonne of wheat worth $ 4.7 million had gone wasted (CAG 2022). Many similar cases have also been cited in news reports, for example, a nationally recognized news media reported a loss of about 1,068 million tons of food grains in Food Corporation of India (FCI) depots (Hindustan Times 2020). As per May 2019 price index, the total post-harvest losses within the country was about $ 6,830 million (CIPHET 2020) of which about $16,000 was for food grains (ASSOCHAM 2022). In these reports, evaluation of the causes of these storage losses were summarized in the form of poor management, lack of adequate facilities and large budgetary deficits. However, as opined by of different experts, like in other developing countries the government agencies of India and their policies have failed to fill the gap of the uneven social and spatial distribution of GR benefits, among favourable and unfavourable marginal and less favoured areas (herein after we will use the term "marginal") which has led to these situations (Malek et al. 2017). Accordingly, the grain management policies adopted on the basis of subsidies have risked the financial health of these agencies, which is more noticeable in recent past due to fuel price hike and lack of funding from private partners (Malek et al. 2017, Taylan et al. 2015). In addition, forced selling of the surplus produce during harvest and reluctance among marginal

Farmers to increase and improve their own storage capacities have overburdened the national agencies, which are mandated to work even beyond their capacities (Singh 2010, Ganesh Kumar 1992). Therefore, concerns have been raised as the expected rise in agriculture productivity owing to introduction and use of more hybrid crops, would further complicate the situation, if new and innovative measure to reduce storage losses are not adopted at this stage (Gao and Hailu 2013, Singh 2010).

In India, in the context of technology, following traditional 'pipeline approach' (Malek et al. 2017, during last few decades several organizations and institutions including- governmental; national/international; private sector; non-governmental organizations (NGOs) etc. have undertaken a lot of work and studies related to development of new technology for farmers, for references see (Kumar and Kalita 2017, Gao and Hailu 2013, Parfitt et al. 2010). Some of these solutions were designed to cover specific commodities (Naveenaa et al. 2017), whereas others were found either impractical to or unadopted by the small farmers (Gao and Hailu 2013). In response to these insights, several experts and international organizations have favoured the development and adoption of demand-driven 'holistic' approach instead of traditional 'pipeline approach' (Malek et al. 2017, Singh 2010).

In India, marginal farmers represent about 80% of the agriculture community, share around 83% of the total land holdings and contribute around 70% of the annual crop production of which 52% is through cereals production (Dhillon 2023). Therefore, the future food security of the country substantially depends on the performance of subsistence farming and reduction of seed or grain losses at their levels during storage must be perceived among the major priorities. In India, two broad categories of storage structures are predominantly used by the farmers depending on their resources: traditional or indigenous structures and new or modern storage structures (Karthikeyan et al. 2009, Mann et al. 2016). The traditional storage facilities include various structures designed and mastered by ancient and/or local farming communities across the country. Their design and application vary with agroclimatic conditions and are made from a variety of locally available materials (Naveenaa et al. 2017).

The modern storage structures include storage facilities developed and designed by different research and development organizations and commercial suppliers across the country (Mann et al. 2016). Several previous studies have compared both traditional and modern structures, in terms of their efficiency to provide safety to stored commodity, and a sheer conflict could be observed among them. Arguments, in support of modern structures claims their better functioning in terms of temperature, humidity control and their efficient control of rodents and pests (Kumar and Kalita 2017, Naveenaa et al. 2017). Similarly, for traditional structures, it has been claimed, that since these structures have evolved around certain specific agroclimatic conditions, they are suitable for storing grains in their original conditions only (Mann et al. 2016, Karthikeyan et al. 2009, Lamichaney et.al. 2019). In addition, they have also reported their benefits, in terms of efficiency, associated cost and eco-friendly nature. Most of the post-green revolution cultivars grown today are often more susceptible to storage losses and for the sake of arguments. Despite all efforts, in the background of all these arguments, it is also true, that due to various reasons adoption of modern structures has mostly been limited and mostly the subsistence farmers lack enough seeds to support their different needs (Naveenaa et al. 2017).

Usually, the comparison of different grain storage practices is assessed using techniques that involve quantitative attributes like construction material and variations observed in physio-chemical and biological properties of the stored commodity during a specified period of time. However, in practice, selection of an appropriate storage structure depends on several qualitative attributes, like their socio-economic status, cultural ethnicity, future crop expectations, availability of transportation etc. (Mann et al. 2016, Karthikeyan et al. 2009. Hence, any evaluation process must simultaneously integrate all these quantitative and qualitative attributes during assessment.

Decision based on the traditional operations research models mostly include the risks of ignoring the effect of different qualitative factors, on the other hand attempting to include these qualitative factors may risk the decision being unscientific or ad-hoc nature of the methods. Additionally, the unavailability of precise data also limits the utility of traditional operations research models in analyzing agricultural decisions (Alphonce 1997). Unfortunately, current agricultural statistics of India sometimes lacks quality, precision and reliability (Dev 2012, Parfitt et al. 2010). Several studies have been conducted on the traditional food grain storage practices of Indian societies, but there is a lack of research on the commercial food grain storage practices.

With this background, we aimed to take a closer look at the grain storage technologies available and used, in a view to identify the gaps and possibility of improvement therein. Also, we used the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and the Analytic Hierarchy Process (AHP) based hybrid multi-attribute decision model in present study to overcome existing complications with other tools.

Material and Methods

For any multi-criteria evaluation process, the primary step is always to determine the attributes or parameters that would be included in the study therefore in this study, employed the Analytic Hierarchy Process (AHP) and Multi-Criteria Decision Making (MCDM) approach to evaluate the commercial food grain storage practices of Indian societies. The study utilized a range of materials, including food grains, storage containers, and analytical equipment to conduct the evaluation of commercial food grain storage practices.

Data were collected through a combination of field observations, interviews with stakeholders, and analysis of existing data sources. In the present study, following activities were carried out to achieve the objectives.

Characterization of Storage Structures:

The range of structures available and used varies geographically. It is diverse in design and continuously modified across generations based on use and experience by our ancestors or by the scientist based on scientific experiments. To get a comprehensive coverage, structures were selected on the basis of their design, crop coverage and perceived benefits, cost involved etc. through literature and experts' judgments. In this study, three most commonly grain storage structures were considered based on their popularity and wide usability in India. These structures/systems were godowns (warehouses), CAP (Cover and Plinth) and gain Silo.

The features of storage practices were identified based on the selected parameters through the literature review, expert judgments and personal observations (Table 1). For performance evaluation and comparison, different parameters essential for effective storage of grains were selected. Overall ten important parameters viz. temperature control, humidity control, efficiency of plant protestants used, protection against insects and pests, strength of the storage structure, storage capacity, life span of structure, shelf life of grain, handling and cost were identified through literature review and experts' suggestion and were prioritized through analytical hierarchy process (AHP). These practices are used by different community located in different geographical areas for different crops. Majority of the community are using maximum two or three grain storage practices and can share their experience. Getting the primary and first-hand data by the same users for all the grain storage structures and then comparison was found difficult. Therefore, a questioner was prepared and sent to all of them with standard instructions based on these; the criteria for measurement were developed. Each and every storage practices was scored based on the criteria (Table 2).

AHP-TOPSIS Technique

The weights for the parameters were calculated by utilizing AHP. The AHP is one of different methods used for the analysis of complicated decisions or multi criteria decision making (Saaty 2008). AHP has been extensively used in decision making processes like health care, business, government, education and others. This method is based on pair-wise comparison and provides scenario checking ability to the researchers and thus helps classifying goals and ways in one complicated environment. The weights assigned to each parameter were used to compute weighed normalized decision matrix. Whereas, TOPSIS method selects the best alternatives which have the nearest distance to the Positive Ideal Solution and farthest distance to the Negative Ideal Solution (Momeni et al. 2011). Further, Euclidean distance was used to compute the distances between each alternative and both the positive-ideal and the negative-ideal solutions. Based on the distance, closeness coefficient is computed to determine the ranking (Taylan et al. 2015).

The steps of hybrid AHP-TOPSIS methodology adopted in this paper are as follows:

Step 1: Define the Problem: Clearly identify decision goal, a set of alternatives and relevant criteria (factors to consider).

Step 2: Gather Information: Collect data on the performance of each alternative against each criterion and the formation of hierarchical model were done.

Step 3: Two types of pair wise comparisons are made in the AHP. The first one was between the factor pairs within the same hierarchical level which involves analyst inputs of relative importance ratings based on the pair wise comparative ratings. We refer to Saaty (1996) for the details of pair-wise comparison scale used in the study. The factors weights are computed and used in the final hierarchical merit aggregation process. This work is done by pair-wise comparison two by two and through dedicating numeral scores which shows priority and majority between two decision elements.

Step 4: The traditional eigen vector method, is the weight vector and is the goal for present study. It helps in measuring the consistency of the referee's preference arranged in comparison matrix. The Consistency Index (CI) measures the degree of logical consistency among pair-wise comparisons and was used in same manner as defined previously by Saaty (1996). Ensure consistency by calculating the Consistency Ratio (CR). If CR > 0.1 (generally accepted threshold), revise our comparisons until achieving consistency.

For AHP, the aggregated final priorities of the alternatives were calculated. Based on that, the weights were constituted and respective weights were used for further analysis. We have selected three commonly used commercial grain storage structures and classified all these on ten parameters.

Step 5: Apply TOPSIS

1. **Decision Matrix:** Constructed a table with alternatives as rows and criteria as columns. Fill in the table with the performance scores for each alternative on each criterion.
2. **Normalize the Matrix:** Since criteria may have different units, normalize the decision matrix. Common methods include ratio normalization.

Step 6: Identify Ideal Solutions

1. **Ideal Positive Solution (PIS):** This is a hypothetical alternative that maximizes benefit criteria and minimizes cost criteria (doesn't exist in reality). Calculate the weighted normalized score for each criterion across all alternatives to find the best performing value for each criterion. This represents the PIS.
2. **Ideal Negative Solution (NIS):** This is another hypothetical alternative that minimizes benefit criteria and maximizes cost criteria (doesn't exist in reality). Similar to PIS, calculate the weighted normalized score for each criterion where the worst performing value across all alternatives represents the NIS.

Step 7: Calculate Distances

Distance from PIS and NIS: For each alternative, calculate the Euclidean distance from both the PIS and NIS in the normalized decision space.

Step 8: Rank the Alternatives

1. **Similarity to Ideal Solution:** The alternative with the **shortest distance to PIS** and **farthest distance to NIS** is the most preferred choice.

2. **Ranking:** Rank the remaining alternatives based on their **closeness** (similarity) to the ideal positive solution (PIS). The alternative with the highest similarity score is ranked second, and so on.

Software Tools:

The Expert Choice software tool was used for AHP-TOPSIS calculations. However, the core steps can be performed manually using ms-excel spreadsheets.

Results and Discussion

Criteria and Composite Scores of Ideal Seed Storage Structure

The result of survey of specialists based on the AHP methods is depicted in table 3. It indicates the parameters for ideal grain storage practices, their percent weight and eigen vectors. The highest weight was obtained by the parameter temperature control (20.6%) followed by humidity control (19.6 %), protection from rodents (14.3 %), efficiency of plant protestants used (14.3 %) and so on. The consistency index CI was found 0.147 and CR value was calculated as 0.099. These percent score has been further used as weights of respective seed storage parameters. By using the criteria of measurement (Table 3) each storage structures were scored parameter wise (Table 4).

Rank of the grain storage practices based on Composite Score Value

Taking after the AHP TOPSIS methodology, the decision matrix is made and presented in Table 2. Results indicated that each storage structures scored parameter wise, on a scale from 1 to 7, where 1 is the worst rating and 7 the best, respectively. By applying AHP-TOPSIS methodology, the decision matrix is normalized and the weighted normalized matrix is computed (Table 4). Following the ideal and negative ideal solutions (PIS and NIS) are determined, as shown in Table 5. Then, with the distance from PIS and NIS are calculated respectively, as are shown in table 5. Eventually, the ranking was calculated and the score of each storage structure is calculated. According to the analysis, metal silo storage system was estimated as the best grain storage structure with 0.933 score followed by warehouse with 0.899 score.

In addition, among all the grain storage practices, metal silo was also preferred because of its strength; huge capacity and long-life span. Metal based structures provide comparatively, air-tight module, which do not let pest and pathogens to enter the structure. Moreover, air-tight nature inhibits the growth of any pest and pathogen present from the beginning, due restriction imposed by limited supply of oxygen within the structure (Kumar and Kalita 2017, Tefera et al. 2011, Abass et al. 2014).

Efficient use of storage technology prevents post-harvest food losses thereby reducing wastage of food and resources used to produce them from very beginning to their final destination in the hands of consumers. All, of these saving provides benefits in form of more sustainable crop production system as well as more socio-economic benefits to poor communities. India, losses a considerable amount of its produce during storage period which in part could be attributed to the poor seed storage infrastructure and lack of knowledge among farm community (Singh 2010, Mann et al. 2016). Thus, for country like India, it is imperative to understand the usefulness, science, technicality and limitations imposed by the design of storage structures in light of above parameters.

The study proposed a methodology to identify the qualitative and quantitative parameters to be considered for grain storage practices and ranked them based on quantitative scores. Combining and comparing qualitative parameters with quantitative parameters particularly in case of multi criteria decision making is really difficult because of lack of perfect scale of reference. These multi-criteria decision-making methods offers a comparatively transparent way to test the significance of policy related objectives (Vera-Montenegro et al. 2014a and b, Yang et al. 2011). This study can able provides support for the combination of valuation techniques employed to obtain reliable estimates of attribute values for complex goods. Combining AHP and TOPSIS seems to be a promising alternative to AHP alone and to TOSIS.

Conclusions

The aim of the study was to evaluate different storage structures based on selected criteria, in a view to support decision making. The study figured out the important parameters for designing effective grain storage system. The AHP-TOPSIS technique is used to derive the weights for different parameters impacting the quality. Further, this study would set a paradigm for successful evolution and development of multi-criteria decision making using AHP-TOPSIS hybrid model in postharvest management studies.

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Table 1. Details of the grain storage structures used in the study

	Parameters	Warehouse (Godown)	CAP	Metal bins (Silo)
1	Strength of material	brick, cement Constructed	Polysheets and Foundation	Metal Steel, Steel Framed
2	Capacity	100 - 10000 tones	54 tones per stack	100 -60000 tones
3	Life span of structure	More than 20 years	1-5 yrs	More than 30years
4	Life span of seed	1- 3 Year	Less than 1 Year	5-7 Year
5	Protection from Insect/Pest	Yes (Medium)	No	Yes (Very high)
6	Temperature control	Yes	No	Yes
7	Humidity control	Medium	No	Yes
8	Efficiency of seed protectants	Yes (High)	Yes (Low)	Yes (Very High)
9	Handling	Easy	Easy	Difficult
10	Cost	Medium	Low	High

Table 2. Assigned scores to the commercial grains storage structures based on selected parameters

	Parameters	Warehouse (Godown)	CAP	Metal bins (Silo)
1	Strength of material	6	5	7
2	Capacity	5	5	7
3	Life span of structure	6	3	7
4	Life span of seed	3	1	5
5	Protection from Insect/Pest	4	3	5
6	Temperature control	5	3	5
7	Humidity control	5	3	5
8	Efficiency of seed protectants	5	3	5

9	Handling	1	1	0
10	Cost	-3	-1	-5

I. Strength of material: Concrete/cement and bricks =1, Polysheet/leather/wood=3, metal sheet=7

II. Capacity to store: upto 100 tones = 1, upto1000 tones = 3, upto1000 tones = 5, >10000 tones =7

III. Life span of structure: upto 2 years=1, 2-5 years=3, 5-10 years=5, >10 years=7

IV. Life span of seed/grain: 2 year=1, upto 5 year=3, >5 years=5

V. Protection from Insect/Pest: low=1, medium=3, high=5

VI. Temperature control: low=1, medium=3, high=5

VII. Humidity control: low=1, medium=3, high=5

VIII. Protectants: not used =0, used of botanicals or chemicals =1, use of both botanicals and chemicals=3

IX. Handling: Easy = 1, difficult=0

X. Cost: low = -1, medium = -3, high = -5

Table 3: Selected parameters of grain storage structures on scale of 1to7 and their weights

Parameter	Measurement(assigned value)	Weights (out of 1)
Temperature control (C1)	low=1,medium=4,high=7	0.206
Humidity control (C2)	low=1,medium=4,high=7	0.196
Efficiency of plant protectants used (C3)	Not used=1, used of botanicals or chemicals=4, use of both botanicals and chemicals=7	0.143
Protection from rodents (C4)	low=1, medium=4, high=7	0.115
Strength of material (C5)	Concrete/cement and bricks =1, Polysheet/leather/wood =3, metal sheet=7	0.121
Capacity to store (C6)	Upto50kg=1,upto5q=3,5- 15q=5, >15q=7	0.104
Life span of structure (C7)	Upto2years=1,2-5years=3,5- 10years=5, >10years=7	0.046
Life span of seed (C8)	Upto 2year=1, upto 5year=4, >5years = 7	0.027

Handling (C9)	Easy=7, difficult=1	0.011
Cost (C10)	low=7,medium=4,high=1	0.031

Note: CI value 0.147; CR value0.099

Table 4. Decision matrix, normalized decision matrix and weighted normalized decision matrix of the grain storage structures

C1	**D**	7	4	7
	ND	0.387	0.221	0.387
	WN	0.081	0.046	0.081
C2	**D**	7	4	7
	ND	0.387	0.221	0.387
	WN	0.076	0.043	0.076
C3	**D**	7	4	7
	ND	0.37	0.211	0.37
	WN	0.048	0.027	0.048
C4	**D**	7	4	7
	ND	0.429	0.245	0.429
	WN	0.058	0.033	0.058
C5	**D**	7	5	7
	ND	0.413	0.295	0.413
	WN	0.047	0.034	0.047
C6	**D**	5	5	7
	ND	0.258	0.258	0.362
	WN	0.021	0.021	0.03
C7	**D**	7	3	7
	ND	0.392	0.168	0.392
	WN	0.018	0.007	0.018
C8	**D**	4	1	7
	ND	0.296	0.074	0.518
	WN	0.011	0.002	0.019
C9	**D**	7	7	1
	ND	0.3	0.3	0.043
	WN	0.006	0.006	0.001
C10	**D**	1	4	1
	ND	0.058	0.232	0.058
	WN	0.001	0.005	0.001

D = Decision Matrix; ND = Normalized Decision matrix; WN = Weighted normalized Decision matrix; C1-C10= parameters in table 1