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Inbound and outbound logistics in a hybrid maize seed processing unit: A statistically tested case study from Telangana, India

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ABSTRACT

Logistics performance is central to a seed processing enterprise, since procurement timing, storage conditions and dispatch reliability jointly determine seed quality, order fulfilment and cost efficiency. Yet seasonal surges in inbound arrivals and outbound demand, combined with informal, experience-based planning, can produce recurring gaps between planned and actual performance that are rarely quantified with statistical rigour. This study examines inbound and outbound logistics at a commercial hybrid maize seed processing unit operated by Bayer CropScience Limited at Shamirpet, Telangana, India, using a descriptive case-study design over a three-month period (March–May 2026). Data were drawn from company transaction records comprising 136 inbound receiving entries, 90 cold-storage log readings, 113 confirmed outbound orders and 110 dispatch runs, supplemented by purposive-sample interviews with seven key functional personnel. Nine performance indicators were benchmarked against internal targets or the International Seed Testing Association (ISTA) storage standard and tested for statistical significance using one-sample t-tests ($\alpha = 0.05$, $df = 2$). Four indicators cold chain compliance, order fill rate, on-time delivery rate and backorder rate showed statistically significant, persistent shortfalls. Two further indicators forecast accuracy and outbound transportation cost rate concealed serious, surge-specific shortfalls in May behind an otherwise strong three-month average, illustrating a divergence between statistical and practical significance. Vehicle capacity utilisation, reconstructed from dispatch records, averaged approximately 80 per cent and remained constant regardless of order volume, implicating under-optimised routing in delivery unreliability. The alternate hypothesis, that significant inefficiency exists in the unit's logistics, is accepted. The study distinguishes a chronic, season-long strain signature from two month-specific signatures (April: inbound coordination; May: demand forecasting and outbound cost), offering a time-sequenced basis for managerial intervention.

Keywords: Seed supply chain, Inbound logistics, Outbound logistics, Hybrid maize seed, Cold chain compliance, Order fill rate, Case study, Telangana

1. Introduction

Agriculture remains foundational to global food security, rural livelihoods and, in many developing economies, national economic stability. The transition from subsistence to market-oriented, technologically intensive farming has been accompanied by the parallel development of a formal seed industry that converts biological and genetic research into a physical input farmers can purchase, store and sow with confidence. International experience shows that the competitiveness of a seed industry depends not only on the genetic quality of the varieties it develops, but equally on the efficiency of the logistics systems that convert research output into farm-level availability: a hybrid variety bred for substantial yield advantage confers no benefit if the seed reaches the field late, physiologically deteriorated, or in insufficient quantity.

In India, agriculture supports 46.1 per cent of the total workforce and, together with allied activities, contributed 17.8 per cent to national Gross Domestic Product in 2023-24, growing 5.4 per cent during 2024-25 (Ministry of Statistics and Programme Implementation [MoSPI], 2025) [1]. Within this framework, the seed industry occupies a strategic position as the first and most critical input in the crop production cycle, since the genetic potential embedded in seed sets the upper limit on productivity that subsequent agronomic management can realise. India's rice production reached a record 149.07 million metric tonnes in 2024-25, while kharif maize production reached an all-time high of 24.54 million metric tonnes, nearly 10 per cent above the previous year (IndiFoodbey, 2025) [2] gains inseparably linked to the availability of quality seed in adequate quantity, at the right time and at an affordable price. The Indian seed industry itself was valued at approximately USD 7.8 billion in 2024 (IMARC Group, 2025) [3] and ranks as the world's fifth-largest seed market, accounting for 4.4 per cent of the global seed market (Expert Research Market, 2025) [4], propelled substantially by hybrid seed technology in maize, cotton and vegetables.

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Telangana occupies a distinctive position within this industry, popularly described as the “Seed Capital of India” on account of favourable agro-climatic conditions, an established network of contract seed growers, and the presence of major domestic and multinational seed companies including Bayer CropScience, Corteva Agriscience, Syngenta, Advanta Seeds and Kaveri Seeds, with processing infrastructure concentrated around Hyderabad. Logistics management in this setting acquires distinctive features relative to general supply chain contexts: seed is a living biological entity whose quality deteriorates with improper handling, moisture control or temperature exposure; demand is sharply seasonal and geographically variable, governed by sowing calendars; and operations are subject to certification and storage standards such as those of the International Seed Testing Association (ISTA). Logistics functions in a seed processing enterprise are conventionally analysed as inbound logistics (procurement, receiving, storage and processing of raw seed) and outbound logistics (order processing, packaging, dispatch scheduling and last-mile delivery of processed seed) two dimensions that, although analytically distinguishable, are operationally interdependent, such that bottlenecks at any single stage propagate consequences through the remainder of the chain.

Despite the acknowledged importance of logistics to seed industry competitiveness, much of Indian agricultural economics research has historically emphasised plant breeding and agronomic dimensions rather than logistics performance measurement at the level of an individual processing unit. Supply chain optimisation in agricultural procurement and distribution has been reported to yield efficiency gains of 15–20 per cent (Doborjginidze *et al.*, 2021) [5], digital tracking systems have been linked with reductions in distribution losses of 35–40 per cent and forecast-error and stockout ranges of 22–25 per cent and 18–22 per cent respectively in Indian seed distribution (Kumar *et al.*, 2023) [6], and systematic vehicle-routing and dispatch planning has been shown to reduce total logistics costs by up to 40 per cent (Fernando *et al.*, 2024) [7]. This study addresses the resulting gap by examining the logistics chain of a commercial hybrid maize seed processing unit in Telangana, with the following specific objectives: (1) to understand the inbound and outbound logistics processes involved in a maize seed processing unit; (2) to evaluate the efficiency of inbound and outbound logistics against relevant performance benchmarks; and (3) to analyse the basis of dispatch fleet planning and implementation and suggest measures for improvement. The study tests the null hypothesis (H_0) that there is no significant inefficiency in the study unit's inbound and outbound logistics, against the alternate hypothesis (H_1) that significant inefficiency exists.

2. Materials and Methods

2.1 Research design

The study employed a descriptive case-study research design, considered appropriate because it facilitates in-depth examination of operational processes within a single organisation under real-life conditions without altering the operational environment. The design integrated information from personal interactions with key officials, direct observation of logistics operations, and examination of company records, systematically organised to characterise the existing logistics framework, identify operational strengths and constraints, and suggest measures for improving efficiency.

2.2 Study area

The study was carried out at the Bayer CropScience Limited Maize Seed Processing Unit located at Shamirpet, Medchal–Malkajgiri District, Telangana, on the northern outskirts of Hyderabad. Bayer AG is a global life-science company headquartered in Leverkusen, Germany; in India, Bayer CropScience Limited is a leading agribusiness engaged in crop protection, hybrid seed production and digital farming, with its seed business spanning research, hybrid seed production, processing, quality assurance, storage and nationwide distribution. The unit was selected on the basis of its established logistics

system, modern processing infrastructure and extensive hybrid maize distribution network. The study area experiences a tropical semi-arid climate (700–900 mm average annual rainfall, temperatures ranging 15–42 °C) favourable for hybrid maize seed production and processing, and benefits from well-developed transport connectivity to Hyderabad.

2.3 Sampling procedure

As the investigation was a case study, purposive sampling was used to select seven key personnel directly involved in the planning, supervision and execution of logistics operations: the Plant Manager, Logistics Manager, Warehouse Manager, Production/Processing Manager, Quality Control Personnel, Procurement Executive and Warehouse Supervisor. This ensured that primary information was drawn from individuals with direct, functional responsibility for the processes under study.

2.4 Study period and data collection

The study was conducted over three months, March to May 2026. Primary data were collected through personal interviews and direct observation of receiving, unloading, drying, shelling, processing, packaging, warehousing and dispatch operations. Secondary data, used to compute all quantitative efficiency measures, were compiled from the unit's own transaction records: 136 inbound receiving entries, 90 cold-storage log readings, 113 confirmed outbound orders and 110 dispatch runs.

2.5 Performance indicators and statistical analysis

Nine performance indicators were computed on a monthly basis and evaluated against internally planned benchmarks or, for cold chain compliance, the ISTA storage standard of 100 per cent: procurement lead time, inbound transportation cost rate, seed receipt rejection rate and cold chain compliance rate (inbound); and order fill rate, on-time delivery rate, backorder rate, outbound transportation cost rate and forecast accuracy (outbound). A supporting vehicle capacity utilisation indicator was reconstructed directly from load carried against rated capacity across all 110 dispatch runs. For each metric, the three-month sample mean was compared with its benchmark through gap analysis, and the statistical significance of the deviation was tested using a one-sample *t*-test at the 5 per cent level (critical $t = 4.303$, $df = 2$, two-tailed), appropriate to a three-monthly observation sample. Throughout the analysis, statistical significance (a result unlikely to be due to ordinary month-to-month variation) was kept distinct from practical significance (a result large enough to matter operationally, irrespective of the statistical verdict).

3. Results and Discussion

3.1 Inbound and outbound process structure

Inbound logistics at the unit runs through five sequential stages: procurement planning, field harvest and collection, receiving and inspection, storage, and processing. Procurement planning translates the season's processing plan into grower-level collection windows revised on a rolling basis. Field harvest and collection use a mixed transport arrangement whose composition shifted materially over the study window: company-arranged loads accounted for 58 per cent of March receipts but only 38 per cent of April receipts, before settling near an even split (53 per cent) in May. Average inbound moisture declined steadily from 15.3 per cent in March to 13.4 per cent in April and 12.1 per cent in May, tracking closely with the falling rejection rate discussed below.

Outbound logistics runs through four stages: order processing, packaging, dispatch scheduling and vehicle routing, and last-mile delivery. Confirmed outbound order volume rose sharply across the study window from 16 orders in March to 46 in April and 51 in May, a near-tripling that is the clearest quantitative signature of the pre-sowing demand build-up reported by respondents. Dispatch runs rose correspondingly, from 20 in March to 36 in April and 54 in May.

3.2 Logistics efficiency: gap analysis and hypothesis testing

Table 1 summarises the consolidated gap analysis and hypothesis-testing results for all nine metrics.

Table 1. Consolidated gap analysis and one-sample t-test results for inbound and outbound logistics metrics, March–May 2026 (n = 3 monthly observations per metric). pp = percentage points.

Metric	Mean	Benchmark	Gap	t-value	Decision on H0
Procurement lead time (days)	7.34	5.00	+2.34	2.54	Not rejected
Inbound transportation cost rate (%)	10.28	8.00	+2.28 pp	3.67	Not rejected
Seed receipt rejection rate (%)	4.11	5.00	−0.89 pp	−0.85	Not rejected
Cold chain compliance rate (%)	85.80	100.00	−14.20 pp	−6.57	Rejected
Order fill rate (%)	92.85	95.00	−2.15 pp	−4.90	Rejected
On-time delivery rate (%)	85.12	90.00	−4.88 pp	−4.55	Rejected
Backorder rate (%)	7.15	5.00	+2.15 pp	4.90	Rejected
Outbound transportation cost rate (%)	6.96	6.00	+0.96 pp	2.54	Not rejected
Forecast accuracy (%)	88.17	90.00	−1.83 pp	−0.39	Not rejected

3.2.1 Inbound metrics

Procurement lead time averaged 7.34 days against a 5-day benchmark, an overrun of 47 per cent, rising from 5.50 days in March to 8.36 in April and 8.15 in May a sustained two-month shift consistent with the move toward grower-arranged transport, rather than a single disrupted month. Inbound transportation cost rate followed a similar step-change pattern, averaging 10.28 per cent against an 8 per cent benchmark and rising from 9.04 per cent in March to approximately 10.9 per cent in April and May, coinciding with the same shift toward less consolidated transport. Neither gap reached statistical significance at this sample size, but both are practically persistent.

Seed receipt rejection rate, by contrast, averaged 4.11 per cent against a 5 per cent benchmark an average that beat target, falling steadily from 5.82 per cent in March to 2.21 per cent in May as average inbound moisture declined from 15.3 to 12.1 per cent. This indicates that unseasonal, pre-monsoon moisture pressure was concentrated early in the collection window and had eased substantially by May. Cold chain compliance rate showed the sharpest inbound shortfall: an average of 85.80 per cent against the ISTA-mandated 100 per cent ($t = -6.57$, exceeding the critical value), falling from 90.13 per cent in March to 83.58 per cent in April and plateauing at 83.70 per cent in May. Total seed volume in storage rose steadily across the period while climate-controlled capacity did not expand to match, so an increasing share of stock was diverted to less precisely controlled supplementary storage; the April-onward plateau indicates that climate-controlled capacity became the binding constraint at that point rather than compliance deteriorating continuously.

3.2.2 Outbound metrics

Order fill rate averaged 92.85 per cent against a 95 per cent benchmark ($t = -4.90$, significant), remaining in a narrow band (92.29–93.71 per cent) across all three months even as order volume nearly tripled indicating a structural gap between processed-inventory availability and confirmed demand that did not close as volumes grew. Backorder rate, mechanically linked to fill rate, averaged 7.15 per cent against a 5 per cent benchmark ($t = 4.90$, significant), following a U-shaped pattern across the three months consistent with a persistent, roughly constant proportional shortfall rather than a single bad month.

On-time delivery rate averaged 85.12 per cent against a 90 per cent benchmark ($t = -4.55$, significant), with its weakest reading in April (83.33 per cent) rather than the higher-volume month of May (87.04 per cent), while vehicle capacity utilisation stayed essentially flat

across both months suggesting the April dip reflects inbound coordination strain spilling into outbound scheduling, rather than volume pressure. Outbound transportation cost rate averaged 6.96 per cent against a 6 per cent benchmark ($t = 2.54$, not significant), but the entire three-month gap originates in May, when the rate jumped to 7.71 per cent, corroborated by dispatch log entries flagging “pre-sowing dispatch strain” from 2 May onward. Forecast accuracy averaged 88.17 per cent against a 90 per cent benchmark ($t = -0.39$, not significant) but collapsed from 93.14 per cent in April to 78.92 per cent in May a fall of roughly fourteen percentage points coinciding exactly with the pre-sowing order surge. In both cases, a real and operationally serious May-specific shortfall is masked, at the level of the three-month average, by two comparatively strong preceding months, illustrating a clear divergence between statistical and practical significance.

3.3 Dispatch fleet planning and vehicle capacity utilisation

Dispatch routing at the unit relies on informal, experience-based planning rather than a formal optimisation methodology. Vehicle capacity utilisation, reconstructed directly from load carried against rated capacity for all 110 dispatch runs, averaged approximately 80 per cent and remained essentially constant regardless of monthly order volume (20 runs in March, 36 in April, 54 in May). This near-constant utilisation, unresponsive to substantial swings in dispatch volume, points to under-optimised routing rather than fleet capacity shortage as a contributing factor in both the confirmed on-time delivery shortfall and the May rise in outbound transportation cost.

3.4 Month-wise strain signatures

Synthesising the month-wise results identifies three distinguishable strain signatures within the study window rather than a single undifferentiated episode of weakness. First, a chronic, season-long signature present every month and statistically confirmed comprising cold chain compliance, order fill rate and backorder rate, requiring structural remedies such as expanded climate-controlled storage capacity and closer alignment of processing throughput with confirmed demand. Second, an April-concentrated inbound and scheduling signature, visible in procurement lead time, inbound transportation cost rate and on-time delivery rate, plausibly linked to the shift toward grower-arranged transport and calling for a coordination review timed to that point in the collection calendar. Third, a May-concentrated demand and cost signature, visible in forecast accuracy and outbound transportation cost rate, tied to the onset of the pre-sowing order surge and calling for an early-warning mechanism for forecast drift and pre-

arranged transport capacity timed to the approach of the pre-sowing period.

3.5 Test of hypothesis

Of the nine metrics examined, the null hypothesis (H_0) was rejected for four cold chain compliance rate, order fill rate, on-time delivery rate and backorder rate spanning both inbound and outbound functions. It was not rejected for the remaining five, though at least three of these (procurement lead time, inbound transportation cost rate and outbound transportation cost rate/forecast accuracy in their May-specific form) show real, sustained or surge-specific shortfalls that a three-month test, appropriately conservative at this sample size, does not confirm but does not contradict either. On the balance of evidence, the alternate hypothesis (H_1) that significant inefficiency exists in the study unit's inbound and outbound logistics is accepted.

4. Practical and managerial implications

The findings suggest four priority areas for managerial action. First, the chronic shortfalls in cold chain compliance, order fill rate and backorder rate indicate that climate-controlled storage capacity and processed inventory planning are structurally undersized relative to current seed volumes and are unlikely to self-correct without capacity investment or tighter inventory-to-demand alignment. Second, the April-concentrated inbound and scheduling strain suggests that a co-ordination review timed to the point in the collection calendar when grower-arranged transport becomes dominant could jointly improve procurement lead time, inbound transport cost and on-time delivery. Third, the May-concentrated demand and cost signature points to the value of an early-warning mechanism for forecast drift and pre-arranged transport capacity, timed specifically to the approach of the pre-sowing period. Fourth, the near-constant 80 per cent vehicle capacity utilisation, irrespective of order volume, suggests that a more formal, load-optimised routing approach sequencing multi-stop delivery runs by destination clustering, delivery time windows and available capacity could recover unused capacity and improve both delivery reliability and per-unit transportation cost without additional fleet investment. Ongoing monitoring of vehicle capacity utilisation as a standing, records-based outbound metric is recommended.

5. Limitations of the study

The three-month reference period limits each metric to only three-monthly observations, raising the statistical bar for significance and meaning that real, sizeable single-month issues notably May's forecast accuracy and outbound transportation cost results do not register as statistically confirmed despite being practically significant. The reconstructed vehicle capacity utilisation figure, although computed directly from dispatch records, reflects only this unit's own fleet and routing practices during this period, and the study's generalisability to other processing units or seasons has not been tested. A longer observation window spanning multiple seasons would allow greater statistical power to confirm these patterns.

6. Conclusion

This study establishes that the logistics chain of the Shamirpet hybrid maize seed processing unit performs reliably in some respects notably seed receipt rejection rate, which improved over the season and met benchmark on average but exhibits a persistent, statistically confirmed, multi-month shortfall in cold chain compliance, order fill rate, on-time delivery rate and backorder rate, alongside distinct, time-bound strains concentrated in April (inbound coordination and scheduling) and May (demand forecasting and outbound transport cost). Vehicle capacity utilisation, held constant at around 80 per cent regardless of order volume, further implicates under-optimised routing in delivery reliability and transport cost outcomes. By distinguishing chronic, structural shortfalls from month-specific strain signatures, and by separating statistically confirmed results from practically significant ones, the study offers a precise, evidence-based, and se-

quenced basis for strengthening logistics efficiency structural fixes applied continuously to storage capacity and inventory planning, a co-ordination review timed to the April inbound transport shift, surge-readiness measures timed to the May pre-sowing period, and a formal routing methodology to recover unused vehicle capacity. This approach, grounded in nine directly measured and statistically tested performance indicators rather than a single seasonal average, has broader relevance for hybrid seed processing units operating under comparably compressed, seasonally peaked supply chains.

References

1. MoSPI (Ministry of Statistics and Programme Implementation). National Accounts 2025. Government of India. 2025.
2. IndiFoodbey. Kharif maize production hits all-time high of 24.54 MMT in 2024-25. IndiFoodbey; 2025.
3. IMARC Group. India seed market: Industry trends, share, size, growth, opportunity and forecast 2025-2033. IMARC Group; 2025.
4. Expert Research Market. Global seed market report. Expert Research Market; 2025.
5. Doborjginidze G, Petriashvili L, Inaishvili M. Optimization of inventory management in the supply chain. *Journal of Communication and Computer*. 2021;16(1):1-10.
6. Kumar R, Sharma P. Supply chain challenges in Indian seed distribution. *Journal of Agribusiness Management*. 2023;27(1):112-129.
7. Fernando J, Silva R, Costa M. An integrated vehicle routing model to optimize agricultural products distribution in retail chains. *Engineering Applications of Artificial Intelligence*. 2024;130:107715.

BIBLIOGRAPHY.

9. Bello PC, Olaoje GO. Seed viability preservation in tropical storage conditions. *Seed Science Research*. 2022;38(3):215-230.
10. DoA and FW (Department of Agriculture and Farmers Welfare). National Seed Policy Implementation Audit Report. Government of India; 2023.
11. Eveline C, Kithika S, Charles C, James O, Abeid T. Effects of inventory management techniques on procurement performance: An empirical study. *International Journal of Supply Chain Management*. 2019;8(3):45-54.
12. Harrington JF. Seed Storage and Longevity (5th ed.). Academic Press; 2023.
13. ICAR. Climate Resilience in Agricultural Storage Systems. New Delhi: Indian Council of Agricultural Research; 2023.
14. Kadam D, Chouhan D, Roy T, Prajapati H, Nandeha N, Mishra N, Roopal. Digital agriculture: The future of Indian agriculture. *International Journal of Environment and Climate Change*. 2023;13:3963-3976.
15. Kaynov I, Van Knippenberg M, Menkovski V, Van Breemen A, Van Jaarsveld W. Deep reinforcement learning for one-warehouse multi-retailer inventory management. *International Journal of Production Economics*. 2024;267:10-18.
16. Kumar S, Chakraborty P. Optimizing supply chain management in seed cooperatives: Enhancing efficiency, quality, and accessibility in seed distribution networks. *International Journal of Applied and Behavioural Sciences (IJABS)*. 2025;12(1):280-295.
17. Lahari D, Reddy TS, Radhika P, Supriya K. Returns management of maize and paddy seeds. *Journal of Scientific Research and Reports*. 2024;30(9):77-85.
18. Marahatta S. Assessment of the effectiveness of storage structures for maintaining the quality of maize seed stored at different moisture levels. *Journal of Agriculture and Natural Resources*. 2021;4(1):96-110.
19. NITI Aayog. Doubling Farmers' Income: Mid-Term Review and Revised Roadmap. Government of India. 2023.

20. NSAI. Annual Industry Report 2023. National Seed Association of India, New Delhi. 2023.
21. PLFS. Annual Report 2023-24. Ministry of Labour and Employment, Government of India. 2023.
22. QCI. Seed Certification Benchmarking Report 2023. New Delhi: Quality Council of India. 2023.
23. Rice News Today. India's rice production reaches record 149.07 MMT in 2024-25. Rice News Today. 2025.
24. TSSOCA. Annual Certification Performance Report 2023. Telangana State Seed and Organic Certification Authority. 2023.
25. Zhang B, Mohammad J. Sustainability of perishable food cold chain logistics: A systematic literature review. *SAGE Open*. 2024;14(3):1-28.

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