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Supply chain efficiency of a fertilizer distribution network in Andhra Pradesh

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Abstract

Research on India's fertilizer sector has concentrated on manufacturing capacity and subsidy policy, leaving the stretch of chain between the factory gate and the field comparatively unexamined. This paper measures the efficiency of that stretch as the people working inside it experience it. One hundred participants in the distribution network of Coromandel International Limited in Kakinada district of Andhra Pradesh, including company officials, authorized distributors, retail dealers, farmers and transport operators rated an identical set of eighteen statements covering logistics reliability, cost efficiency and dealer relationship quality on a five-point scale and supplied factual operating indicators for their own tier. The scales were internally consistent ($\alpha = 0.810-0.840$; 0.919 for the full module). The network was assessed as efficient overall (mean 3.688; $t = 14.15$, $p < 0.001$ against the scale midpoint), but the assessment was uneven in two ways. Relationship quality was the strongest dimension (3.848) and cost efficiency the weakest (3.503), in that order within every tier without exception. Overall efficiency also differed significantly across tiers ($F = 3.633$, $p = 0.016$, $\eta^2 = 0.102$; Kruskal-Wallis $p = 0.037$), the difference being carried by logistics reliability ($p = 0.033$) and cost efficiency (Welch's $p = 0.024$) but not by relationship quality ($p = 0.083$). Post-hoc testing isolated a single significant contrast: retail dealers rated the network higher than farmers, placing the perception gap at the last link rather than upstream. Operating data corroborated it, replenishment took three to seven days for 70.0 per cent of dealers against under three days for every distributor, and 80.0 per cent of vehicles waited over two hours at the loading point, the aspect drawing the lowest satisfaction rating recorded (3.00). Price discipline, by contrast, was complete. The findings caution against treating channel-partner satisfaction as a proxy for network efficiency

Keywords: Fertilizer distribution; supply chain efficiency; stakeholder perception; last-mile logistics; vehicle turnaround; Andhra Pradesh

Introduction

Fertilizer is examined in Indian agricultural scholarship chiefly at its two ends. One body of work studies manufacturing: plant efficiency, feedstock economics, and capacity utilisation. Another studies the fiscal end: the nutrient-based subsidy, direct benefit transfer, retail price control. Between them lies the part of the system that a cultivator actually meets: bagged product moving from plant or port through distributors and retail dealers to the village counter, carried by contracted road transport and constrained by two short, unforgiving demand peaks. It is on this stretch that timeliness, landed cost and service quality are settled, and it is this stretch that has attracted the least empirical attention (Ministry of Chemicals and Fertilizers, 2024) ^[7]. The work that does address distribution tends to look at it from one vantage point at a time. Mohanty and Senthil Kumar (2017) ^[9] measured farmers' satisfaction and loyalty towards fertilizer brands and found engagement and service to be as decisive as the product itself, and later work on repurchase behaviour reinforced the role of the selling interface (Mohanty and Patro, 2020) ^[8]. Parikh *et al.* (2024) ^[11] approached the same system from the operations side, tracing cost inefficiencies in imported fertilizer logistics through stakeholder interaction and field observation and identifying peak-season wagon shortage and high handling charges as the principal frictions. Saini and Savita (2025) ^[12], studying a different agricultural channel, show how sharply a supplier's assessment of a marketing arrangement can diverge from the assessment of the producer at the other end of it. That divergence is the point of departure here. Efficiency in a distribution network is usually reported as a property of the firm and is usually

evidenced by the Satisfaction of its channel partners. But a despatch that a dealer records as punctual may still reach the farmer after the sowing window has narrowed; a freight rate that a planner regards as competitive may be quietly absorbed by a carrier whose vehicle stands idle at a loading bay for six hours. If these experiences differ systematically by position in the chain, then any assessment drawn from a single tier, most often the tier closest to the company, will be biased in a predictable direction, and the improvement agenda built on it will be aimed at the wrong place. This paper therefore measures the same construct, in the same words, at every level of one network, and asks three questions. First, how efficient is the network when judged by all of its participants together? Second, do the tiers differ significantly in that judgement, and if so on which dimensions? Third, where in day-to-day operations does the shortfall actually arise? The null hypothesis tested is that there is no significant difference in overall supply chain efficiency, comprising logistics reliability, and cost efficiency and dealer relationship quality, among the stakeholder tiers of the network.

Materials and Methods

Study setting: The study was a cross-sectional survey conducted in Kakinada district of Andhra Pradesh between

March and June 2026. The district was selected because the whole downstream chain is physically present within it: Coromandel International Limited operates a manufacturing complex and a captive port facility at Kakinada, from which its distributors, retail dealers, contracted carriers and farmer customers can all be reached (Coromandel International Limited, 2024). Kakinada is also among the more fertilizer-intensive districts of coastal Andhra Pradesh, with paddy-dominated cropping that concentrates demand into two sharp seasonal peaks precisely the condition under which distribution networks are tested.

Sample: One hundred respondents were drawn across five participant categories, using sampling methods appropriate to each respondent category (Table 1). Company officials, authorized distributors and transport operators are small, bounded populations whose members are not interchangeable, so purposive selection was used; dealers and farmers were drawn by stratified random sampling within mandal strata. For analysis the five categories were reduced to four tiers, with officials and distributors combined into a single supply-side tier. The two groups plan and despatch rather than receive, their raw scores were closely similar, and neither on its own ($n = 5$) would support a stable variance estimate.

Table 1: Composition of the sample and assignment to analytical tiers

Respondent category	Sampling method	n	Analytical tier	Tier n
Company officials	Purposive	5	Supply-side	10
Authorized distributors	Purposive	5	Supply-side	
Retail fertilizer dealers	Stratified random	40	Retail dealers	40
Farmers	Stratified random	40	Farmers	40
Transport and logistics providers	Purposive	10	Transporters	10
Total		100		100

Instrument: Efficiency was operationalised through three dimensions, each measured by six statements answered on a five-point agreement scale. Logistics reliability covered on-time delivery, order completeness, condition of bags on arrival, peak-season stock adequacy, schedule adherence and responsiveness to urgent requirements. Cost efficiency covered freight and handling charges, conformity of prices to notified retail rates, storage and holding costs, wastage and losses, transparency of margins, and overall cost competitiveness. Dealer relationship quality covered communication, grievance settlement, mutual trust, technical and promotional support, honouring of commitments, and general cordiality. This eighteen-statement core module was administered identically to all 100 respondents, which is what makes the tiers directly comparable. Each schedule additionally carried a tier-specific section recording factual operating indicators (replenishment lead time, stock-out frequency, vehicle waiting time, timeliness at the farm gate, payment above the maximum retail price) and satisfaction ratings on the service aspects relevant to that role. Schedules were pre-tested on respondents outside the sample and were administered in Telugu wherever the respondent preferred it.

Analysis: Internal consistency was assessed by Cronbach's alpha (Cronbach, 1951)^[3], against the conventional 0.70 threshold (Nunnally, 1978)^[10]. Dimension and overall scores were tested against the neutral midpoint of 3.00 by one-sample t-tests. Before comparing tiers, normality was checked within tiers by the Shapiro-Wilk test (Shapiro and Wilk, 1965)^[13] and equality of variances by Levene's test on median-centred deviations

(Levene, 1960)^[6]. Tier differences were then tested by one-way analysis of variance, with Welch's correction (Welch, 1951)^[15] substituted where variances were unequal, and with the Kruskal-Wallis test (Kruskal and Wallis, 1952)^[5] as a distribution-free robustness check on the overall score. Significant results were decomposed by Tukey's HSD (Tukey, 1949)^[14], or by Games-Howell (Games and Howell, 1976)^[4] where variances were unequal. Effect sizes were reported as eta squared and interpreted following Cohen (1988)^[1]. Relationships among dimensions were examined by Pearson's correlation. All tests were conducted at the five per cent level; computation was carried out in Python 3 using pandas and SciPy. Three qualifications should be read alongside the results. The analysis treats five-point agreement scores as interval data, which is standard practice but not uncontroversial; the Kruskal-Wallis check is reported partly for this reason. The supply-side and transporter tiers are small ($n = 10$), so the study has limited power to detect differences involving them, and non-significance for those contrasts should not be read as evidence of equality. Finally, the core module measures experience rather than audited performance; the operating indicators were introduced specifically to anchor the perceptual findings in observable facts.

Results and Discussion

Reliability and the overall assessment of the network

The scales held together well. Cronbach's alpha was 0.822 for logistics reliability, 0.810 for cost efficiency and 0.840 for

dealer relationship quality, and 0.919 for the eighteen statements combined, comfortably above the accepted threshold. No statement improved its dimension by deletion, so all were retained. Judged as a whole, the network is efficient. The pooled overall score of 3.688 on the five-point scale lies well above the neutral midpoint ($t = 14.15$, $p < 0.001$), and each dimension does so individually (Table 2). What the pooled figure conceals, however, is that efficiency is not evenly distributed neither across the three dimensions nor across the four tiers. Relationship quality is the strongest

dimension (3.848), logistics reliability is sound (3.713), and cost efficiency is the clear laggard (3.503). This ordering recurs within every single tier, including the company's own officials (Figure 1), which makes the relative weakness of cost a structural feature of the system rather than the grievance of any one group. Cost efficiency in fact slips to the moderate band among farmers (3.329) and transporters (3.400), the two tiers that pay freight and purchase cost out of their own pockets.

Table 2: Efficiency scores by stakeholder tier, with tests against the scale midpoint (mean, with SD in parentheses)

Stakeholder tier	n	Logistics reliability	Cost efficiency	Dealer relationship quality	Overall efficiency
Supply-side	10	3.800 (0.532)	3.783 (0.539)	4.067 (0.534)	3.883 (0.508)
Retail dealers	40	3.888 (0.518)	3.633 (0.552)	3.975 (0.580)	3.832 (0.490)
Farmers	40	3.558 (0.528)	3.329 (0.397)	3.717 (0.576)	3.535 (0.442)
Transporters	10	3.550 (0.545)	3.400 (0.654)	3.650 (0.481)	3.533 (0.441)
Pooled	100	3.713 (0.542)	3.503 (0.525)	3.848 (0.577)	3.688 (0.487)
t against 3.00 (df = 99)		13.17	9.59	14.70	14.15
p value		< 0.001	< 0.001	< 0.001	< 0.001
Cronbach's α		0.822	0.810	0.840	0.919*

*Alpha for the full eighteen-statement module.

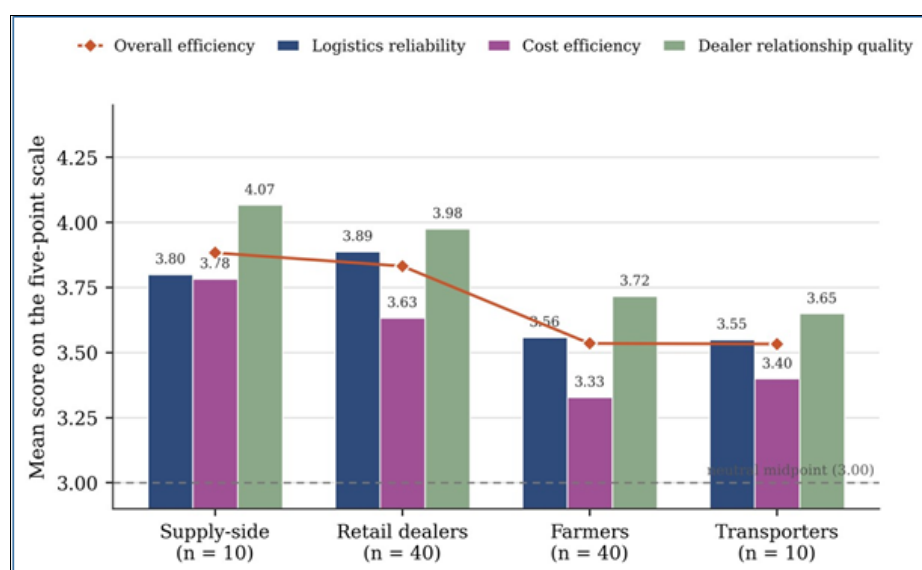


Figure 1. Mean scores of the three efficiency dimensions and of overall efficiency, by stakeholder tier. The ordering of dimensions: relationship quality highest, cost efficiency lowest is identical in all four tiers, while the level shifts downward from the dealer counter to the farm gate and the road.

Do the tiers agree? Testing the hypothesis

Shapiro-Wilk tests returned p values above 0.05 in all four tiers, so the parametric route was available. Levene's test found equal variances for the overall score, logistics reliability and relationship quality, but not for cost efficiency ($p = 0.040$), which was therefore taken through Welch's ANOVA and Games-Howell comparisons. The null hypothesis is rejected. Overall supply chain efficiency differs significantly across the four tiers ($F = 3.633$, $p = 0.016$), with eta squared of 0.102; about a tenth of the variation in efficiency scores is attributable simply to where a respondent stands in the chain, a medium effect by Cohen's (1988)^[1] benchmarks. The Kruskal-Wallis test returns the same verdict ($H = 8.494$, $p = 0.037$), so the conclusion does not depend on the distributional assumption. The dimension-wise results locate the disagreement precisely (Table 3). Logistics reliability and cost efficiency both differ significantly across tiers; dealer relationship quality does not ($p = 0.083$). Trust, communication and support are experienced

with reasonable uniformity along the chain, whereas dependability of delivery and burden of cost are not. This is a useful asymmetry: the relational fabric of the network is holding the system together, and the disputes are operational.

Post-hoc testing then narrows the finding further, and somewhat unexpectedly. Only one pair of tiers separates significantly, and it is the same pair every time retail dealers rate the network higher than farmers, on the overall score (difference 0.297, $p = 0.028$), on logistics reliability (0.329, $p = 0.031$) and on cost efficiency (0.304, $p = 0.030$). The gap therefore opens not between the company and its channel, where one might expect it, but at the very last link, between the dealer's counter and the field. The largest raw difference in the study was in fact between the supply-side tier and farmers (0.349), yet it fell short of significance; with only ten supply-side respondents this is a matter of power rather than of evidence for equality, and the point deserves stating plainly. It is also worth noting that the transporters' ratings were statistically indistinguishable from the

farmers. The carriers who physically move the material share the end user's more reserved view of the network, a convergence

between the two tiers that sit outside the company's formal channel machinery.

Table 3: Tests of differences in efficiency across the four stakeholder tiers (N = 100)

Variable	Test applied	Statistic	df	p	η^2	Significant contrast (post-hoc)
Overall efficiency	One-way ANOVA	F = 3.633	3, 96	0.016	0.102	Dealers > Farmers (0.297, p = 0.028) a
Overall efficiency	Kruskal- Wallis	H = 8.494	3	0.037	-	robustness check
Logistics reliability	One-way ANOVA	F = 3.033	3, 96	0.033	0.087	Dealers > Farmers (0.329, p = 0.031) a
Cost efficiency	Welch's ANOVA	F = 3.777	3, 23.6	0.024	0.102	Dealers > Farmers (0.304, p = 0.030) b
Dealer relationship quality	One-way ANOVA	F = 2.295	3, 96	0.083	0.067	None

a Tukey's HSD b Games-Howell, applied because Levene's test indicated unequal variances (p = 0.040). No other tier pair reached significance on any variable.

Where the efficiency is actually lost

Ranking all eighteen statements by mean score turns the diagnosis into an agenda (Figure 2). The six weakest statements are, without exception, either cost items or peak-season items: overall cost competitiveness (3.41), freight and handling charges (3.45), transparency of margins (3.47), holding costs (3.48), peak-season stock adequacy (3.50) and responsiveness to urgent requirements (3.57). At the other end sit mutual trust and

cordiality (3.92 each) and adherence to delivery schedules (3.86). Taken together, the profile describes a network that is dependable and well-regarded in ordinary weeks and comes under strain exactly when crop demand concentrates which is when it matters. The concentration of weakness in freight-related items agrees closely with Parikh *et al.* (2024) ^[11], who identified handling and peak-season capacity as the dominant cost frictions in Indian fertilizer logistics.

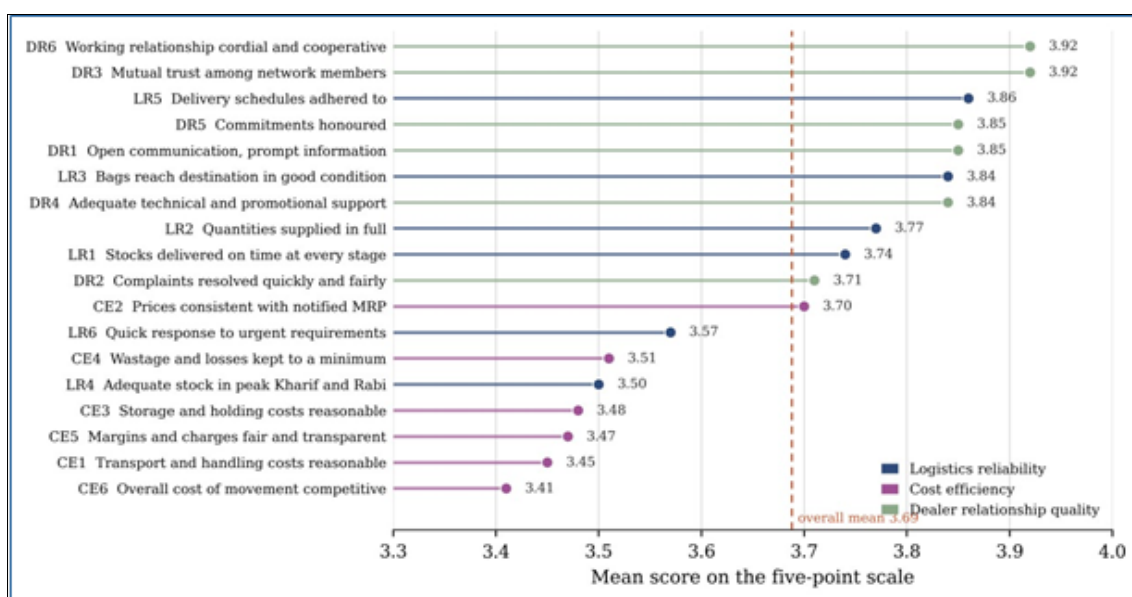


Fig 2: Mean scores of the eighteen core statements in ascending order, shaded by dimension. Every statement in the lower third belongs to cost efficiency or to peak-season logistics; the relational statements occupy the top of the distribution.

The tier-specific operating indicators show how these ratings are generated (Figure 3). A distinct lead-time step exists inside the channel: every distributor receives replenishment within three days of ordering, but only 20.0 per cent of dealers do, while 70.0 per cent wait three to seven days and 10.0 per cent longer than a week. The primary leg of the chain runs to a same-week standard that the secondary leg does not meet, and the delay accumulates one step before the farmer. Dealers absorb the risk by ordering early and carrying protective stock which is why peak-season stock-outs remain rare (90.0 per cent report never or rarely) even as those same dealers rate holding costs guardedly. At the other end of the chain, 80.0 per cent of transporters wait more than two hours for loading at the plant or port and 30.0 per cent wait between four and eight hours, despite receiving at least two days' despatch notice. Detention on this scale raises the effective cost of every

trip and reduces the number of trips a vehicle can complete in the peak season, feeding simultaneously into the cost items and the peak-season responsiveness items of the core module. The convergence is exact: turnaround time drew a satisfaction rating of 3.00 from the transporters, the lowest score recorded anywhere in the study. At the farm gate the record is good but incomplete 87.5 per cent of farmers received fertilizer always or mostly on time, and 12.5 per cent only sometimes. On price, by contrast, the network is beyond criticism: not one of the forty farmers had ever paid above the printed maximum retail price, which independently corroborates the comparatively high rating of the price-conformity statement. The service gap at the farm level is therefore a gap of timing, not of pricing, a distinction with direct implications for what the company should attempt to fix.

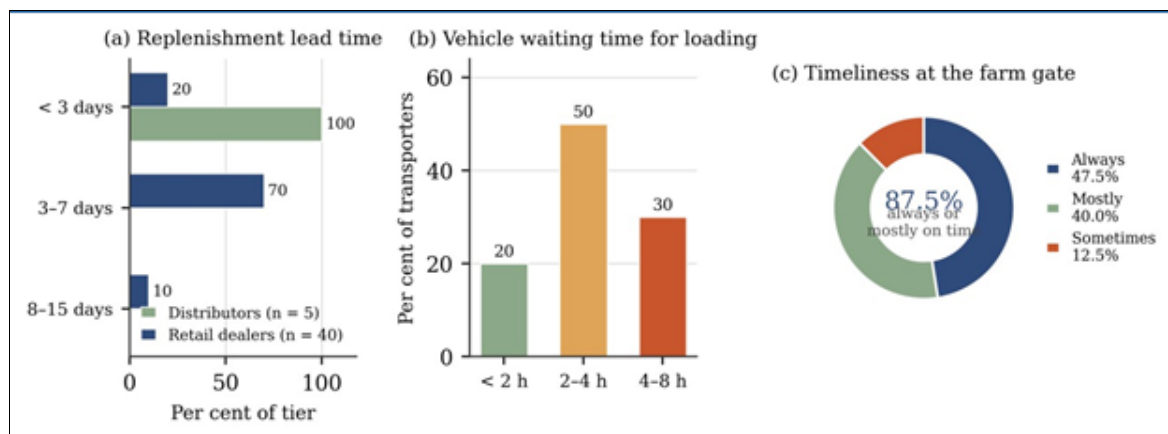


Fig 3: Operating indicators behind the perception gap: (a) replenishment lead time for distributors and retail dealers; (b) average vehicle waiting time for loading at the plant or port; (c) timeliness of fertilizer availability reported by farmers

The three dimensions are strongly and positively intercorrelated ($r = 0.628$ to 0.727 , $p < 0.01$), and each correlate very strongly with the overall score ($r = 0.865$ to 0.913). Two things follow. Methodologically, combining them into a composite is defensible, they measure related facets of one underlying experience. Practically, they move together: an improvement made on reliability can be expected to lift perceptions of cost and of the relationship as well, which is an argument for concentrating effort on a small number of operational fixes rather than spreading it thinly.

Four implications follow directly from the evidence. Scheduled loading slots with vehicle turnaround tracked as a routine performance indicator address the single most concrete and most cheaply remediable gap found; reducing detention lowers effective freight cost and releases carrying capacity in the peak season without any addition to the fleet. Compressing dealer replenishment towards the standard already achieved on the distributor leg through firm despatch commitments and route-wise delivery days would reduce the protective inventory dealers now carry and improve availability where it is weakest. Pre-positioning stock ahead of the Kharif and Rabi peaks on district-level forecasts secures peak-season adequacy in advance rather than chasing it. And because the perception gap sits between the counter and the field, advance stock-arrival advisories issued to farmers in Telugu, through dealers and mobile messaging, address the deficit at the point where it actually occurs.

Conclusion

Measured from within, the fertilizer distribution network studied here is an efficient one, and its relational strength is real. But the measurement is only informative because it was taken at every level. Had the same instrument been administered to the company's officials and its dealers alone the tiers ordinarily surveyed the network would have returned a score of roughly 3.84 and a clean bill of health. Adding the farmers and the carriers lowers that to 3.688 and, more importantly, exposes a statistically significant step at the last link that the upper tiers cannot see from where they stand.

The substantive contribution is therefore methodological as much as empirical: channel-partner satisfaction alone may not be an adequate proxy for overall network efficiency, because the partners are precisely the tier best served by the network. The operational contribution is that the shortfall proved traceable and small in scope: vehicle detention at the loading point, a lead-time step on the secondary leg, and thin communication to the farm tier rather than diffuse. None of the three requires capital expenditure to address.

The study is confined to one company, one district and one point in time, and it measures experience rather than audited cost and service records. Replication across companies and districts, and a design that tracks the same network through a full Kharif and Rabi cycle against despatch documentation, would establish how far the last-link gap reported here is a general property of agricultural input distribution rather than a local one.

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