Accompanied Or Unaccompanied? Terminal Capability and The Economic Viability of Truck-On-Train Services on India's Western Dedicated Freight Corridor

Ashok Kumar Mishra[1], Chandrahauns R. Chavan[2]
[1]*Research Scholar, Jamnalal Bajaj Institute of Management Studies, University of Mumbai, Mumbai, India*
[2]*Professor and Former Director, Jamnalal Bajaj Institute of Management Studies, University of Mumbai, Mumbai, India*

***Abstract*—On 13 December 2025 the Swiss rolling highway across the Alps ceased operation, having lost money in 2024 at eighty per cent capacity utilisation and with federal support. Six months earlier, Indian Railways was expanding truck-on-train services on the Western Dedicated Freight Corridor. This paper asks why one country is scaling up the technology another is retiring, and whether the Indian service is economically viable. Three door-to-door cost functions are specified for a single truckload consignment: self-driven road haulage, unaccompanied combined transport in which the container is lifted on to rail, and accompanied combined transport in which the entire vehicle is carried. The models are parameterised from published institutional sources and from the tender documents of the corridor operator, and are examined through crossover analysis, a two-dimensional regime map over haul and drayage distance, a terminal-cost threshold analysis, one-at-a-time sensitivity testing and Monte Carlo simulation over sixty thousand draws. A separate operator condition tests whether the published tariffs cover the published haulage charge at the observed load factor. Accompanied transport carries the worst payload efficiency of the three modes, 42 per cent against 51 per cent for single-stack containers and 64 per cent for road, yet it delivers the lowest door-to-door cost on the corridor: 32.1 per cent below road and 21.6 per cent below unaccompanied rail. It overtakes road at a haul of only 105 kilometres, where unaccompanied transport requires 570; and unaccompanied transport does not overtake it until 1,522 kilometres, or 880 kilometres if double-stack loading is available. The threshold that separates the two technologies is terminal capability: at a drayage distance of seventy kilometres, unaccompanied transport is not cheaper even if lifting were free. Against this, the operator condition fails. At the published slab tariff the service must carry 30.8 trucks per rake to cover the tender haulage charge, and the observed load factor is approximately 25. The paper supplies the first economic model of accompanied combined transport in India, and generalises the Indian and Swiss cases into a single testable proposition: accompanied transport is the correct technology precisely where terminals are expensive and distant from shippers, and it is displaced by unaccompanied transport once that ceases to be true. It is, on this reading, a transitional technology whose success would eventually justify its own retirement.**

***Index Terms*—Accompanied combined transport, break-even distance, dedicated freight corridor, India, modal shift, roll-on roll-off rail, terminal cost, truck-on-train**

I. INTRODUCTION

On 13 December 2025 the last rolling highway train ran between Freiburg and Novara. RAlpin, the Swiss operator that had carried lorries across the Alps by rail for two decades, closed the service after posting a loss of approximately 2.2 million Swiss francs in 2024 a loss incurred at eighty per cent capacity utilisation and in receipt of federal compensation [1]. The traffic returns to the road until the shippers concerned convert to craneable semi-trailers, which is to say until they can be served by unaccompanied combined transport instead.

In the same period Indian Railways was moving in the opposite direction. Truck-on-train services on the Western Dedicated Freight Corridor, in which a complete road vehicle is driven on to a flat wagon and driven off at the far end, have been expanded from an experimental operation into a scheduled commercial

one. Between New Rewari in Haryana and New Palanpur in Gujarat, a distance of 636 route kilometres, the service has completed more than 1,955 trips, carried in excess of 48,875 trucks and a million tonnes of goods, and earned revenue exceeding ₹131 crore. Transit time is approximately twelve hours against about thirty by road.

Two questions arise, and this paper is organised around them. The first is analytical: under what conditions is it economically rational to carry the vehicle rather than only its load? Carrying the vehicle is manifestly wasteful in engineering terms, since the railway must haul some fourteen tonnes of tractor and trailer that generate no revenue. Yet it eliminates the two operations that the intermodal literature has repeatedly identified as decisive the terminal lift and the road leg at each end. The trade is real and its resolution is not obvious.

The second question is practical: is the Indian service viable as presently priced and loaded? The corridor operator's tender sets a reserve haulage charge of ₹9,00,000 per rake per single trip for a formation of forty-five wagons [2]; the published slab tariff for a truck of twenty-five to forty-five tonnes is ₹29,191. Whether the traffic actually offered covers that charge is a question of arithmetic once the load factor is known, and the reported performance permits the load factor to be inferred.

The paper's contribution is threefold. It supplies what appears to be the first formal cost model of accompanied combined transport in the Indian setting, calibrated on published parameters and validated against a published tariff. It generalises the Indian and Swiss experiences into a single proposition that the choice between accompanied and unaccompanied transport is governed by terminal capability, and that a quantifiable threshold separates the two regimes. And it reports an operator viability condition that the present service does not appear to satisfy, which is a finding of immediate policy relevance to a programme now being extended to further corridors.

What follows is arranged in seven further sections: a review of the combined transport literature and the gap it leaves; the specification of the three cost functions and of the operator's break-even condition; the results; their discussion; and finally, the policy implications, the limitations of the exercise and the conclusion.

II. REVIEW OF LITERATURE

A. Accompanied and Unaccompanied Combined Transport

Combined transport moves a road consignment over a rail line-haul, and it takes two forms. In unaccompanied transport the loading unit alone a container, swap body or craneable semi-trailer is transferred between modes, and the tractor and driver are released for other work. In accompanied transport, generally termed the rolling highway in Europe and roll-on roll-off or truck-on-train in India, the complete vehicle is driven on to a low-floor or flat wagon and the driver travels with it. The distinction is not a detail of loading practice. It determines what equipment a terminal must possess, how long the transfer takes, what the railway must haul, and whether the road asset is idle or productive during the rail leg.

The economic literature has treated the two forms as competing solutions to the same problem, and has generally concluded in favour of the unaccompanied form on the ground of payload efficiency. Accompanied transport requires the railway to move the tare of the road vehicle, which on a modern articulated combination is of the order of fourteen tonnes against a payload of twenty-five, and it consumes loading gauge that could otherwise carry revenue cargo. What that argument omits is the cost of the transfer that the unaccompanied form necessarily incurs, and the value of the time the road asset spends idle while it does so.

B. The Terminal as the Governing Cost

A consistent finding of the intermodal literature is that the terminal, not the line-haul, decides the outcome. Kim and Van Wee [3] estimated the relative influence of a change in the line-haul rate against a change in terminal cost at approximately seven to one in favour of the terminal. Zgonc, Tekavčič and Jakšič [4] put the break-even distance for European intermodal chains anywhere between 103 and 1,143 kilometres, and traced that enormous spread not to the rail leg but to what happens before and after it. The unit values themselves come from Carboni and Dalla Chiara [5], whose European costings put a single transfer at €36–60 and the road leg at €1.23–3.78 for each kilometre a forty-foot unit is dragged. Cavallaro, Nocera and Sommacal [6], examining the Brenner axis, argued that the density and scale of corridor terminals is itself

the policy variable, since a sparse terminal network lengthens drayage and destroys the advantage the rail leg creates.

The maritime side of the literature arrives at the same place. For Notteboom and Rodrigue [7], and for Roso, Woxenius and Lumsden [8], an inland terminal is better understood as a limb of the seaport than as one of the railway's customers, which makes the weakest transfer in the chain the one that sets its performance. Behdani, Wiegmans, Roso and Haralambides [9] find that around three-fifths of what a maritime chain costs are incurred inland.

Read together, this literature implies something that has not, to the authors' knowledge, been stated explicitly: if the terminal governs, then a technology that abolishes the terminal transfer should be advantaged in exactly those settings where terminals are worst. That is the proposition this paper formalises and tests.

C. The European Experience and the Retreat from the Rolling Highway

European accompanied transport was created as an instrument of policy rather than of commerce. Alpine transit constraints, and in Switzerland a constitutional mandate to shift freight from road to rail, produced services that were subsidised from the outset. The RAlpin operation carried up to eighty thousand lorries a year, some seven per cent of Swiss combined Alpine traffic, and its closure at the end of 2025 is instructive precisely because it did not fail for want of custom [1]. Utilisation stood at eighty per cent. It failed because the margin between what shippers would pay and what the operation cost could not absorb the disruption of an increasingly congested rail network, even with compensation. The stated succession plan is conversion to craneable semi-trailers that is, migration to the unaccompanied form.

D. The Indian Experience

India's precedent is the Konkan Railway roll-on roll-off service, introduced to carry lorries past a coastal stretch on which the parallel road is slow and mountainous. Trucks of up to forty tonnes gross and 3.4 metres in height are driven on to modified flat wagons by ramp; loading occupies fifteen to twenty minutes; the driver and cleaner travel in the cab. The tariff published in 2017 for the Kolad–Verna movement was ₹4,856 per vehicle [10]. The service has been operated for more than two decades and is treated within Indian Railways as a success, though it has attracted almost no analytical attention.

The corridor service is different in kind. It runs on purpose-built infrastructure with a twenty-five-tonne axle load and trains of 1,500 metres, over a lane that has a continuous high-standard highway alternative, and it competes against road haulage rather than substituting for a road that does not exist. Its published parameters are unusually complete: forty-five modified flat wagons to a rake, one truck to a wagon, a gross weight limit of sixty-five tonnes per vehicle, a reserve haulage charge of ₹9,00,000 per rake per trip, a minimum guarantee of 450 trips per rake per year, and a scheduled ten-hour transit within a sixteen-hour cycle including loading and unloading [2].

E. The Research Gap

Three gaps follow. First, the analytical literature on accompanied transport is almost wholly European and almost wholly concerned with Alpine transit under subsidy; no economic model of the Indian case exists. Second, the comparison that matters accompanied against unaccompanied, rather than either against road is rarely made explicitly, and where it is made the terminal parameters are European and therefore favourable to the unaccompanied form.

Third, and most consequentially, no study appears to identify the condition under which one technology displaces the other, which is precisely the question raised by the simultaneous Swiss withdrawal and Indian expansion. This paper addresses all three.

III. RESEARCH METHODOLOGY

A. Approach and Unit of Analysis

Three door-to-door cost functions are specified for one truckload consignment of twenty-five tonnes moving between two points served by the corridor. The unit of analysis is the consignment rather than the tonne-kilometre, since the choice under study is made consignment by consignment. Two distinct viability questions are then asked of the same parameter set: whether the shipper is better off, and whether the operator covers its haulage charge. These can and do give different answers, and conflating them is a common error in appraisals of such services.

B. The Three Cost Functions

For self-driven road haulage over distance D, the cost of a consignment is

$$C_{road} = c_r \cdot q \cdot D + w_d \cdot t_r/24 + V \cdot r_v \cdot t_r/8760 + v \cdot r_h \cdot t_r/8760 \quad (4)$$

comprising the road freight cost at c_r per tonne-km on payload q, the driver and crew wage at w_d per day over the transit time t_r, the capital tied up in the vehicle at rate r_v on its value V, and the inventory cost of the cargo at rate r_h on its value v.

For unaccompanied combined transport the vehicle is released, so its capital and its driver do not enter, but two lifts and two road legs do:

$$C_{unacc} = c_g \cdot (T_w + s \cdot (T_c + q))/s \cdot D + n \cdot C_l + c_{dr} \cdot L_{dr} + v \cdot r_h \cdot t_u/8760 \quad (5)$$

where c_g is the rail cost per gross trailing tonne-kilometre, T_w the wagon tare, T_c the container tare, s the number of containers carried in one wagon slot, so that $s = 2$ represents double-stack loading, n the number of lifts at cost C_l each, and c_{dr} the drayage rate over the combined road legs L_{dr}.

For accompanied transport the whole vehicle is hauled and the driver rides with it, but there is no lift and the road legs shrink to the approach to the ramp:

$$C_{acc} = c_g \cdot (T_w + T_t + q) \cdot D + 2 \cdot C_{ramp} + c_r \cdot q \cdot L_{ramp} + w_d \cdot t_a/24 + V \cdot r_v \cdot t_a/8760 + v \cdot r_h \cdot t_a/8760 \quad (6)$$

where T_t is the tare of the road vehicle and *cramp* the drive-on or drive-off handling charge.

Comparing (5) and (6) isolates the paper's central trade: (6) carries T_t in the rail term and retains the driver and vehicle capital, while (5) carries $n \cdot C_l$ and $c_{dr} \cdot L_{dr}$, which (6) does not.

C. Payload Efficiency

Payload efficiency is defined as revenue-earning tonnes divided by gross trailing tonnes, and is reported for each mode because it is the conventional ground on which accompanied transport is criticised. Establishing that the criticism is correct in engineering terms, and yet does not determine the economic outcome, is one of the results of this paper.

D. The Operator Condition

Shipper advantage is necessary but not sufficient. The service is provided by an operator that pays the infrastructure owner a haulage charge H per rake per trip and recovers slab tariffs τ from shippers. Ignoring the operator's own overhead, which is not published, the load factor at which the operation breaks even is

$$k^* = H / \tau \quad (7)$$

and the service covers the haulage charge only where the realised load factor k exceeds k^*. Since k^* rises with H and falls with τ, the condition is reported across the published tariff slabs and across a range of haulage charges rather than at a single point, and the resulting k^* is compared with the load factor implied by reported performance.

E. Parameters

Table I lists every parameter with its base value, range and source. The rail cost per gross trailing tonne-kilometre requires comment because it is not published directly. It is derived by taking the published Indian rail cost of ₹1.41 per net tonne-kilometre [11] and multiplying by a representative payload efficiency of 0.55, giving ₹0.776 per gross tonne-kilometre. Expressing rail cost in gross terms is essential here, since the whole question at issue is how much dead weight each mode obliges the railway to move.

TABLE I Model Parameters, Base Values, Ranges and Sources

Parameter	Symbol	Base value (range)	Source
Rail haul, New Rewari–New Palanpur (km)	D	636	DFCCIL RoRo tender [2]
Equivalent road distance (km)	D_{road}	700	NH-48 / NE-4 alignment
Drayage, unaccompanied, both ends (km)	L_{dr}	70 (30–140)	Assumed; varied widely
Road legs to the ramp, accompanied (km)	L_{ramp}	20 (5–50)	Assumed
Payload per consignment (t)	q	25.0 (15–32)	Typical articulated load
Road vehicle tare (t)	T_t	14.0 (10–18)	Tractor plus trailer

Parameter	Symbol	Base value (range)	Source
Container tare, 40 ft (t)	T_c	3.8	ISO specification
Flat wagon tare (t)	T_w	20.0	BRN / BLC class
Containers per wagon slot	s	1 (2 = double-stack)	WDFC clearance 7,100 mm [13]
Rail cost (₹ per gross tonne-km)	c_g	0.776 (0.60–1.00)	Derived from NITI Aayog & RMI [11]
Lift cost (₹ per container lift)	C_l	4,000 (2,000–6,000)	Carboni & Dalla Chiara [5], transferred
Lifts per movement	n	2	Origin and destination
Ramp handling (₹ per truck per end)	C_{ramp}	500 (200–1,200)	Assumed; drive-on/drive-off
Road freight cost (₹ per tonne-km)	c_r	2.58 (2.13–4.35)	NITI Aayog & RMI [11]; TERI [12]
Drayage rate (₹ per km, 40 ft unit)	c_{dr}	150 (80–250)	Carboni & Dalla Chiara [5], transferred
Road transit, door to door (hours)	t_r	30 (24–40)	Reported comparison for the lane
Accompanied transit, door to door (hours)	t_a	16 (12–24)	DFCCIL tender [2]: 10 h transit, 16 h cycle
Unaccompanied transit, door to door (hours)	t_u	24	Rail leg, dwell and two road legs
Driver and crew wage (₹ per day)	w_d	1,400 (900–2,000)	Assumed
Road vehicle capital (₹)	V	35,00,000 (22–50 lakh)	Assumed
Vehicle capital and depreciation rate	r_v	0.18 (0.12–0.25)	Assumed
Cargo value per consignment (₹)	v	25,00,000 (8 lakh–80 lakh)	Assumed; varied widely
Inventory holding rate	r_h	0.15	Indian working capital cost
Wagons per rake	—	45	DFCCIL RoRo tender [2]
Reserve haulage charge (₹ per rake per trip)	H	9,00,000	DFCCIL RoRo tender [2]
Published slab tariff, 25–45 t (₹ per truck)	τ	29,191	Indian Railways published tariff

Note. Ranges in parentheses are those used in the sensitivity analysis and the Monte Carlo simulation. Money in constant rupees.

F. Validation

The model is validated against a quantity it was not fitted to. The rail cost parameter is derived from a national average published by NITI Aayog; the accompanied transport tariff is set independently by the operator of the corridor service.

If the model's estimate of the rail resource cost of an accompanied movement approximates the published tariff for that movement, the cost basis may be regarded as sound. Section IV-A reports the comparison.

G. Sensitivity, Simulation and Regime Mapping

Four procedures follow. Crossover analysis solves each pairwise cost equality for distance. Regime mapping evaluates all three functions across a grid of haul distance from 150 to 2,000 kilometres and drayage distance from 0 to 200 kilometres, and records which mode is cheapest at each point, once with single-stack and once with double-stack unaccompanied transport. Threshold analysis solves, for each drayage distance, the lift cost at which unaccompanied transport overtakes accompanied transport; this is the quantity that separates the Swiss regime from the Indian one. Finally, one-at-a-time sensitivity and a Monte Carlo simulation of sixty thousand draws, with every parameter sampled from a

triangular distribution over its range, establish robustness.

IV. RESULTS

A. Validation, and the Paradox of Dead Weight

The model estimates the rail resource cost of an accompanied movement over 636 kilometres at ₹29,119. The published slab tariff for a vehicle of twenty-five to forty-five tonnes over that lane is ₹29,191, a difference of 0.2 per cent. The two figures are derived from entirely independent sources a national average cost per net tonne-kilometre on one side and an operator's published tariff on the other and their agreement should not be pressed too hard, but it is a strong indication that the cost basis is correctly scaled.

Table II and Fig. 1 report the three-mode comparison. Accompanied transport has the worst payload efficiency of the three: 42.4 per cent, against 51.2 per cent for single-stack unaccompanied transport, 64.4 per cent for double-stack, and 64.1 per cent for a road vehicle. On the conventional engineering criterion, it is the least efficient way to move the goods. It is nevertheless the cheapest, at ₹34,178 per consignment against ₹43,612 for unaccompanied transport and ₹50,342 by road 32.1 per cent below road and 21.6 per cent below unaccompanied rail.

TABLE II Three-Mode Cost Decomposition, ₹ per Consignment of 25 t over 636 km

Cost component	Road	Unaccomp.	Accomp.
Rail or road line-haul	45,150	24,085	29,119
Transfer (lifts / ramp)	—	8,000	1,000
Road legs to terminal	—	10,500	1,290
Driver and vehicle capital	3,908	—	2,084
Cargo inventory	1,284	1,027	685
Total cost per consignment	50,342	43,612	34,178
Ratio to road	1.000	0.866	0.679
Door-to-door time (hours)	30	24	16
Gross trailing weight (t)	39.0	48.8	59.0
Payload efficiency	64.1%	51.2%	42.4%

Note. Computed from (4), (5) and (6) at the base parameter values of Table I. Unaccompanied transport shown at single-stack loading.

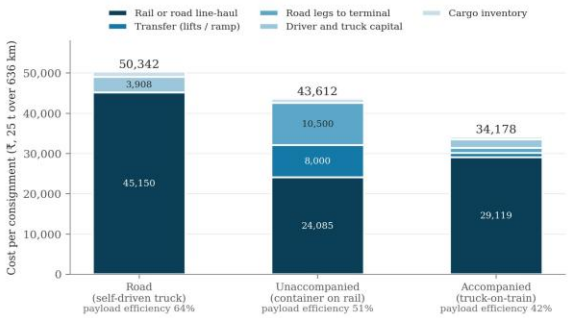


Fig. 1. Cost composition and payload efficiency by mode, 25 t consignment over 636 km.

The reason is visible in the decomposition. Accompanied transport pays ₹5,034 more than unaccompanied transport in rail line-haul, which is the price of the dead weight. Against that it saves ₹8,000 in lifting and ₹9,210 in road legs, and a further ₹342 in inventory because it is faster. The dead weight penalty is real and is exactly what the engineering criticism predicts; it is simply smaller than what the terminal costs.

B. Crossover Distances

Fig. 2 plots the three cost functions against haul distance. Accompanied transport overtakes road at a haul of only 105 kilometres, because it carries almost no fixed cost per consignment: there is no lift, and the road legs are the short approach to the ramp. Unaccompanied transport requires 570 kilometres to overtake road, since it must first recover two lifts and seventy kilometres of drayage. Most importantly, unaccompanied transport does not overtake accompanied transport until 1,522 kilometres at single-stack, or 880 kilometres if double-stack loading is available.

There is therefore a window of haul distance between roughly 105 and 880 kilometres on these parameters in which accompanied transport is the least-cost mode of the three. The Rewari–Palanpur lane at 636 kilometres lies inside that window. This resolves the puzzle with which the paper opened on the Indian side: the service exists on a lane that is too short for conventional intermodal transport to work, and that is precisely the range in which the accompanied form is superior.

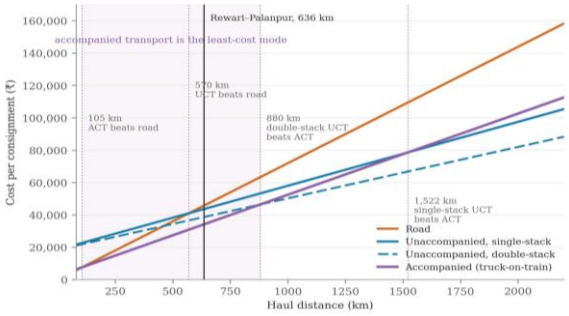


Fig. 2. Cost against haul distance for the three modes, with the crossover distances marked. The shaded band is the range over which accompanied transport is the least-cost mode.

C. The Regime Map

Fig. 3 generalises the result to two dimensions. Over a grid of haul distance and drayage distance, the accompanied form is cheapest across 79 per cent of the plane when unaccompanied transport is confined to single-stack loading, and across 53 per cent when double-stack is available. The boundary slopes upward: the longer the drayage to the inland terminal, the longer the haul must be before unaccompanied transport becomes preferable. At a drayage of 100 kilometres, which is common where terminals are sparse, the accompanied form remains cheapest to beyond 2,000 kilometres even against double-stack.

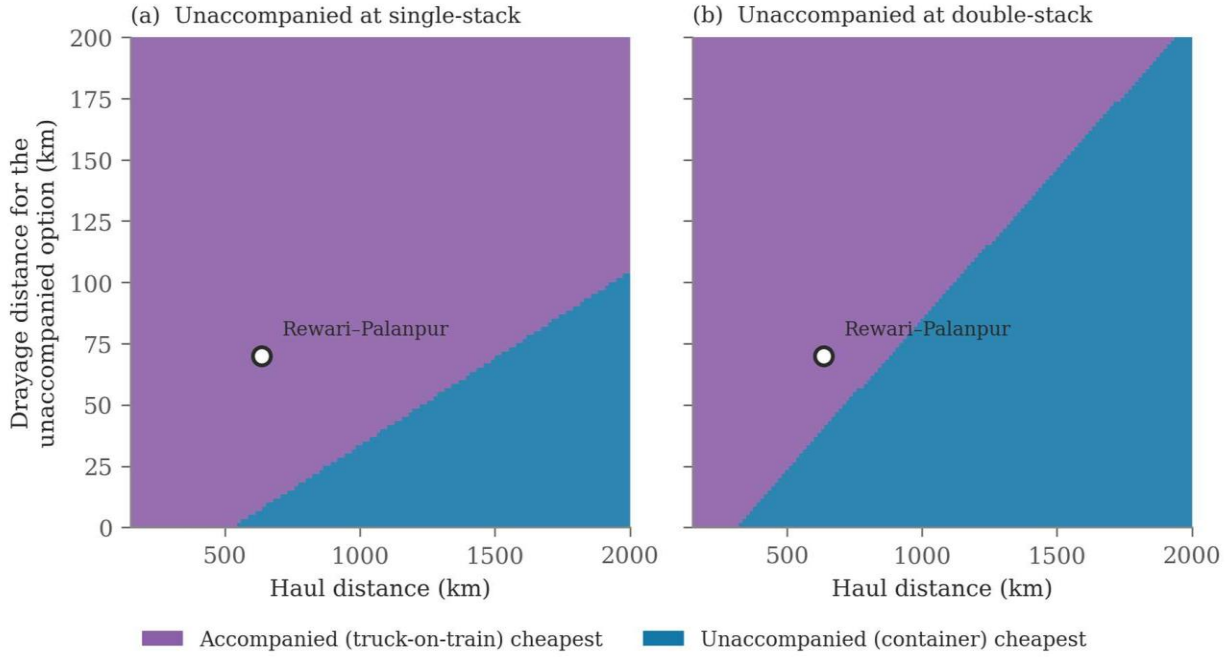


Fig. 3. Least-cost mode over haul distance and drayage distance, with unaccompanied transport at single-stack (a) and double-stack (b) loading.

D. The Terminal Capability Threshold

Fig. 4 states the governing condition directly. For each drayage distance it plots the lift cost at which unaccompanied transport would overtake accompanied transport. At a drayage of twenty kilometres the threshold is ₹3,033 per lift; at forty kilometres it falls to ₹1,533; and at seventy kilometres the value assumed here for Indian inland terminals unaccompanied transport is not cheaper at any lift cost whatever, including zero. With double-stack loading the thresholds relax to ₹5,500, ₹4,000 and ₹1,750 respectively, and unaccompanied transport again becomes unreachable beyond about a hundred kilometres of drayage.

This is the quantitative form of the paper's central proposition. The displacement of accompanied by unaccompanied transport requires two conditions jointly: cheap lifting and terminals close to the shipper. Neither alone is sufficient. Switzerland satisfies both, and has accordingly retired its rolling highway in favour of craneable units. India satisfies neither, and the accompanied form is correspondingly the rational technology there for the present.

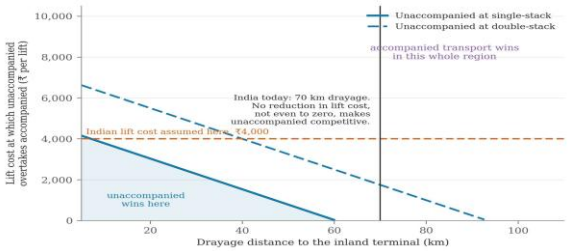


Fig. 4. The terminal capability threshold: the lift cost at which unaccompanied transport overtakes accompanied transport, as a function of drayage distance.

E. Asset Productivity

A consequence of accompanied transport that the per-consignment comparison understates is its effect on the productivity of the road vehicle. Allowing ten hours of turnaround and rest at each end, the round-trip cycle over this lane is eighty hours by road and fifty-two hours by rail. On eight thousand productive hours a year, that is 100 round trips against 154, an increase of 54 per cent, which spreads the vehicle's capital over more revenue trips and reduces the capital charge per trip by 35 per cent.

TABLE III Effect of Truck-on-Train on Road Vehicle Productivity

Measure	Road	Truck-on-train	Change
One-way door-to-door time (h)	30	16	−47%
Round-trip cycle including rest (h)	80	52	−35%
Round trips per vehicle per year	100.0	153.8	+54%
Vehicle capital charge per trip	index 100	index 65	−35%

Note. Assumes ten hours of turnaround and statutory rest at each end and 8,000 productive vehicle-hours a year.

F. Operator Viability

The shipper case is strong; the operator case is not. Table IV and Fig. 5 apply condition (7). At the published slab tariff of ₹29,191 and the tender reserve haulage charge of ₹9,00,000 per rake, the operation must carry 30.8 trucks per rake to cover the haulage charge alone, before any allowance for the operator's own costs. That is 69 per cent of the forty-five-wagon capacity. The load factor implied by reported performance 48,875 trucks over 1,955 trips is approximately 25 trucks per rake, or 56 per cent. On these figures the shortfall is approximately ₹1,70,000 per rake trip. The condition is sensitive to both terms. If the effective haulage charge is ₹7,00,000 rather than the tender reserve, break-even falls to 24 trucks and the observed load factor becomes marginally sufficient. If the traffic is weighted towards the lower slab of ₹25,543, break-even rises to 35.2 trucks, or 78 per cent of capacity. Empty trucks, tariffed at ₹21,894, require 41.1 trucks per rake 91 per cent of capacity which means that a rake carrying a substantial proportion of empties cannot break even at all. The Swiss comparison is sobering rather than encouraging. RAlpin operated at approximately eighty per cent utilisation, with public compensation, and still recorded a loss. The Indian service is operating at roughly fifty-six per cent without, on the published figures, covering its haulage charge.

TABLE IV Operator Break-Even Load Factor under Condition (7), at the Published Slab Tariff of ₹29,191

Haulage charge per rake (₹)	Break-even trucks	% of 45	Against observed 25
7,00,000	24.0	53%	met
8,00,000	27.4	61%	shortfall
9,00,000 (tender reserve)	30.8	69%	shortfall
10,00,000	34.3	76%	shortfall
11,00,000	37.7	84%	shortfall

Note. Covers the haulage charge only; the operator's own costs are not published and are excluded, so the true break-even load factor is higher.

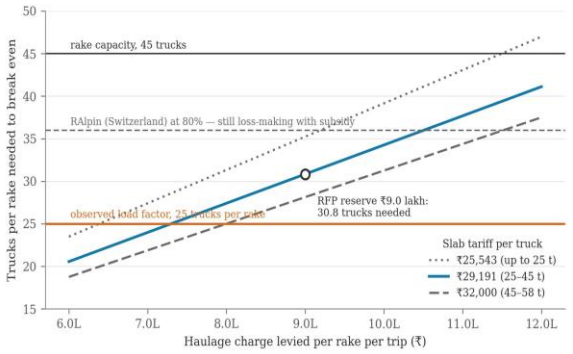


Fig. 5. Operator break-even load factor against the haulage charge levied, for each published tariff slab.

G. Robustness

Sensitivity analysis places the road freight rate first, the rail cost per gross tonne-kilometre second and the payload third among influences on the accompanied-to-road cost ratio; vehicle tare, the parameter at the centre of the engineering objection, ranks only fourth and moves the ratio by 0.078 across its range. The Monte Carlo results in Fig. 6 are decisive on the comparison that matters: accompanied transport is cheaper than road in 98.3 per cent of draws and cheaper than unaccompanied transport in 99.5 per cent, with a median cost ratio against unaccompanied transport of 0.776. Unaccompanied transport itself beats road in only 67.7 per cent of draws at this haul distance and drayage.

H. Emissions

Carrying the dead weight costs almost nothing in carbon terms. Taking Indian rail freight at 9.73 grams of carbon dioxide for each tonne-kilometre and road at roughly 45, one accompanied consignment accounts for 0.388 tonnes and one unaccompanied consignment 0.381, where the same load by road accounts for 0.787.

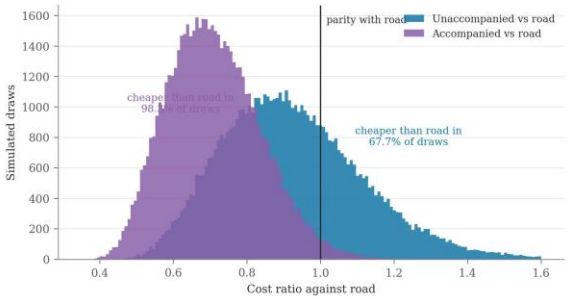


Fig. 6. Simulated distribution of each rail mode's cost ratio against road, 60,000 draws.

The saving against road is 50.8 per cent for the accompanied form and 51.7 per cent for the unaccompanied a difference of less than one percentage point. The environmental case does not discriminate between the two rail technologies, and cannot be used to argue for either.

V. DISCUSSION

A. Why India Adopts What Switzerland Abandons

The two countries are not making opposite judgements about the same problem; they are at different points on the same curve. Accompanied transport buys the elimination of terminal transfer and drayage at the price of hauling dead weight. Where terminals are expensive, sparse and slow, that is a good trade. Where they are cheap, dense and fast, it is a bad one. Switzerland crossed the threshold; India has not reached it. The Swiss succession plan conversion to craneable semi-trailers is not a repudiation of rail freight but a migration to the form of rail freight that a mature terminal network makes cheaper.

That reading has an implication which is uncomfortable for advocates of accompanied transport in India. If the corridor programme succeeds in its terminal ambitions mechanised handling, terminals close to industrial concentrations, lift costs approaching international norms it will move India across the same threshold, and truck-on-train will lose its advantage. Accompanied transport is, on this analysis, a transitional technology. Its correct role is to capture road traffic during the period in which the terminal network is inadequate, and its own success in demonstrating rail's viability contributes to the conditions under which it will be superseded.

B. The Double-Stack Irony

The Western Dedicated Freight Corridor's signature capability is its 7,100-millimetre overhead clearance, which permits containers to be carried two high. A truck cannot be double-stacked. The corridor's most distinctive engineering feature is therefore unavailable to the service under study, and it is precisely the feature that most reduces the threshold at which unaccompanied transport would displace it: double-stack loading moves the crossover from 1,522 to 880 kilometres and takes the accompanied form's share of the regime plane from 79 to 53 per cent. The corridor thus contains, in its own design, the mechanism by which its truck-on-train traffic would eventually be converted to containers.

C. Two Viability Questions, Two Answers

The most policy-relevant result of this paper is the divergence between the shipper case and the operator case. For the shipper the service is compellingly attractive: a third cheaper than driving, half the transit time, and a 54 per cent gain in vehicle productivity.

For the operator, at the observed load factor and the tendered haulage charge, it does not cover its input cost. A service can be simultaneously valuable to its users and unviable to its provider, and when that

happens the traffic grows while the losses grow with it. This is the configuration in which RAlpin ended, and it deserves attention now rather than after the Indian service has been replicated across further corridors.

The remedy indicated by condition (7) is not primarily tariff increases, which would erode the shipper advantage that generates the traffic, but load factor. Moving from 25 to 31 trucks per rake from 56 to 69 per cent of capacity closes the gap at the tendered charge without changing the price to any shipper. The instruments are the familiar ones of consolidation: fewer, fuller departures rather than more frequent thin ones; pricing that discourages empty running, since an empty-heavy rake cannot break even at any load factor below 91 per cent; and directional balancing to raise the utilisation of the return leg.

D. Relation to the Wider Literature

The results extend rather than contradict the terminal-primacy finding of Kim and Van Wee [3] and Zgonc et al. [4]. Those studies established that terminal and drayage costs determine where intermodal transport becomes competitive with road. The present analysis shows that the same parameters also determine which form of intermodal transport is correct, and that the accompanied form is the appropriate response to a poor terminal environment rather than merely an inferior version of the unaccompanied one. It also supports the argument of Cavallaro et al. [6] that terminal density is the operative policy variable, since the regime boundary in Fig. 3 is governed by drayage distance, which is a direct function of how many terminals there are.

VI. POLICY IMPLICATIONS

Four implications follow, in order of the magnitude of their effect in the model.

First, the load factor is the binding constraint on viability, not the tariff. Raising utilisation from 56 to 69 per cent of capacity resolves the operator's shortfall at the tendered haulage charge without any change in what shippers pay. Consolidation of departures, differential pricing against empty running and directional balancing are the instruments; capacity expansion is not.

Second, accompanied transport should be planned as a transitional technology with an explicit succession. Its advantage is contingent on the poor terminal environment it was introduced to circumvent. Where the corridor's terminal programme succeeds, the traffic should be expected and enabled to migrate to containers or craneable units, and rolling stock and ramp investment should be appraised on a horizon consistent with that.

Third, terminal cost and terminal density are the variables that decide which technology is correct. Fig. 4 shows that at seventy kilometres of drayage no reduction in lift cost, however large, makes unaccompanied transport competitive. Terminal siting therefore precedes terminal mechanisation in importance, which inverts the usual order of investment attention.

Fourth, appraisal of such services must separate the shipper case from the operator case. A service that is a third cheaper for its users may still fail to cover the haulage charge levied on its provider, and reporting only user benefit or only traffic growth will conceal this until the accumulated loss forces the issue.

VII. LIMITATIONS

The operator condition rests on a reserve price stated in a tender rather than on the haulage charge actually levied, which is not published; the analysis is therefore reported across a range of charges rather than at a single value, and a lower effective charge would alter the conclusion. The load factor is inferred from aggregate reported performance, not observed directly, and may vary considerably by direction and season. The operator's own costs beyond the haulage charge rolling stock lease, ramp staffing, marketing and administration are not published and are excluded, which means the reported break-even load factor understates the true one.

Two cost parameters, the lift cost and the drayage rate, are transferred from European evidence for want of published Indian series at the required disaggregation. Both are varied widely in the sensitivity analysis and the simulation, and the qualitative conclusions are robust across those ranges, but a primary Indian measurement would materially strengthen the analysis. The rail cost per gross trailing tonne-kilometre is derived rather than observed, and rests on an assumed representative payload efficiency.

Finally, the model is a cost model. It establishes which mode is cheapest and by how much; it does not predict

how much traffic will respond, nor does it capture the non-price attribute's reliability, security, driver welfare, the avoidance of highway checkpoints that plainly influence the decision to place a truck on a train. A stated-preference study of Indian fleet operators would be the natural complement and is the obvious next step.

VIII. CONCLUSION

This paper asked why India is expanding a technology that Switzerland has just abandoned, and whether the Indian service pays. The answers are related.

Accompanied combined transport is the least efficient of the three modes examined in engineering terms and the cheapest in economic terms, because the dead weight it obliges the railway to haul costs less than the terminal transfer and drayage that the unaccompanied alternative cannot avoid. On the Rewari–Palanpur lane it is 32.1 per cent cheaper than road and 21.6 per cent cheaper than containerised rail, it becomes competitive with road at a haul of only 105 kilometres, and it holds its advantage until 880 to 1,522 kilometres depending on whether double-stack loading is available to its rival. Under simulation it is cheaper than road in 98.3 per cent of draws and cheaper than unaccompanied rail in 99.5 per cent.

The condition that governs the choice between the two rail technologies is terminal capability, and it can be stated numerically: at seventy kilometres of drayage to the inland terminal, no reduction in lift cost makes the unaccompanied form competitive. Switzerland long ago fell below that threshold and has migrated accordingly; India has not, and its adoption of accompanied transport is therefore rational rather than anomalous. It follows that the technology is transitional, and that a successful corridor terminal programme will eventually remove the conditions that justify it.

Against this, the operator condition fails on the published figures. Covering the tendered haulage charge requires 30.8 trucks per rake and the service appears to be carrying about 25. The shipper case and the operator case point in opposite directions, and the gap is to be closed by load factor rather than by price. That is the finding with the most immediate bearing on a programme that is now being extended, and it is the one on which further primary data from the corridor operator would be of the greatest value.

REFERENCES

[1] RAlpin AG, "Discontinuation of the rolling highway service between Freiburg and Novara," RAlpin AG, 2025.

[2] Dedicated Freight Corridor Corporation of India Ltd., "Request for proposal: Roll-on roll-off (Ro-Ro) service between New Palanpur and New Rewari on the Western Dedicated Freight Corridor," Ministry of Railways, Government of India, 2021.

[3] N. S. Kim and B. Van Wee, "The relative importance of factors that influence the break-even distance of intermodal freight transport systems," *J. Transp. Geogr.*, vol. 19, no. 4, pp. 859–875, 2011.

[4] B. Zgonc, M. Tekavčič, and M. Jakšič, "The impact of distance on mode choice in freight transport," *Eur. Transp. Res. Rev.*, vol. 11, Art. no. 10, 2019.

[5] A. Carboni and B. Dalla Chiara, "Range of technical-economic competitiveness of rail-road combined transport," *Eur. Transp. Res. Rev.*, vol. 10, Art. no. 45, 2018.

[6] F. Cavallaro, S. Nocera, and G. Sommacal, "Appropriateness of the 'small-scale corridor terminals' scheme for rail-road combined transport: Evidence from the Brenner axis," *Res. Transp. Econ.*, vol. 88, Art. no. 100995, 2021.

[7] T. E. Notteboom and J.-P. Rodrigue, "Port regionalization: Towards a new phase in port development," *Marit. Policy Manag.*, vol. 32, no. 3, pp. 297–313, 2005.

[8] V. Roso, J. Woxenius, and K. Lumsden, "The dry port concept: Connecting container seaports with the hinterland," *J. Transp. Geogr.*, vol. 17, no. 5, pp. 338–345, 2009.

[9] B. Behdani, B. Wiegmans, V. Roso, and H. Haralambides, "Port-hinterland transport and logistics: Emerging trends and frontier research," *Marit. Econ. Logist.*, vol. 22, no. 1, pp. 1–25, 2020.

[10] Konkan Railway Corporation Ltd., "Roll on–roll off services: Operating particulars and tariff," Konkan Railway Corporation Ltd., 2017.

[11] NITI Aayog and Rocky Mountain Institute, *Goods on the Move: Efficiency and Sustainability in Indian Logistics*. Government of India, 2018.

[12] The Energy and Resources Institute, "Increasing rail share in freight transport in India: Moving towards a low-carbon transport future—Working paper: Container," TERI, Project Rep. 2016UD05, 2019.
[13] Dedicated Freight Corridor Corporation of India Ltd., "Western Dedicated Freight Corridor: Project profile and technical parameters," Ministry of Railways, Government of India, 2026.
[14] B. Aritua, J. Havenga, Z. Simpson, and E. W. L. Chiew, "Unlocking India's logistics potential: The value of disaggregated macroscopic freight flow analysis," World Bank, Policy Res. Working Paper 8337, 2018.
[15] W. J. Baumol and H. D. Vinod, "An inventory theoretic model of freight transport demand," *Manage. Sci.*, vol. 16, no. 7, pp. 413–421, 1970.
[16] J. G. Fernald, "Roads to prosperity? Assessing the link between public capital and productivity," *Amer. Econ. Rev.*, vol. 89, no. 3, pp. 619–638, 1999.
[17] M. Gangwar and G. Raghuram, "Framework for structuring container train operations in India," Indian Inst. Manage. Ahmedabad, Working Paper 2010-11-01, 2010.
[18] D. McFadden, "Conditional logit analysis of qualitative choice behavior," in *Frontiers in Econometrics*, P. Zarembka, Ed. New York, NY, USA: Academic Press, 1974, pp. 105–142.
[19] P. Munjal and S. Pohit, "Logistics cost in India: Assessment and long-term framework," National Council of Applied Economic Research, 2023.
[20] C. Winston, "A disaggregate model of the demand for intercity freight transportation," *Econometrica*, vol. 49, no. 4, pp. 981–1006, 1981.