Open Science
BRAZIL

DOI: https://doi.org/10.37497/opsbrazil.54

PREPRINT

TRUCKFULLNESS AND LOOSE LOADING IN LOGISTICS TRANSFERS: A COMPARATIVE STUDY OF THE PALLETIZED METHOD AND TWO LOOSE LOADING SCENARIOS WITH ANNUAL ECONOMIC PROJECTIONS

Truckfullness e carregamento a granel em transferências logísticas: estudo comparativo do método paletizado e de dois cenários de operação a granel com projeção econômica anual

HÉLIO JOÃO ZIGGIATTI SILVA
Mechanical Production Engineer — Universidade Paulista.
E-mail: helio.ziggiatti@gmail.com

ABSTRACT | This study compares palletized tote loading with two loose loading scenarios within the Truckfullness project, involving logistics transfers in Brazil and Mexico. The method combines documentary analysis of the business case, evidence from proof-of-concept tests, and deterministic modeling by route and vehicle. The series of six documented proof-of-concept tests recorded an increase of 30% in the second test and 31.67% in the third test in Brazil; in Mexico, the second test achieved 24.08%. These results support the parameters of 30% and 24% adopted in the projection, preserving differences in vehicles, teams, and operating times across tests. Based on 17,499,686 packages and 1,162 monthly trips, the model estimates 239.38 equivalent trips avoided per month, or 2,872.59 per year, with US$8,064,447.33 in annual gross freight costs avoided. Considering personnel costs based on hours dedicated to each transport unit and the replacement of current handling costs, the projected annual operational benefit is US$5,003,360.16 in S1 and US$7,622,588.76 in S2, before CAPEX. Capacity was calculated using three shifts at origins and two at destinations, seven productive hours per shift, and thirty days per month. In S2, demand utilizes between 19.78% and 98.95% of the service hours allocated to each site. The proof-of-concept tests validate load optimization and support the potential reduction in dispatches; annual benefits represent projections for twelve months of stabilized operations.

Keywords | Logistics; Truckfullness; Loose Loading; Productivity; Transportation Costs.

Submetido: 23-11-2026
Postado: 23-11-2026
e-ISSN: 2764-9822

Endereço de correspondência:
Hélio João Ziggiatti Silva – E-mail: rafael.rosado@safetyware.com.br

RESUMO | Este estudo compara o carregamento paletizado de totes com dois cenários de carregamento a granel no projeto Truckfullness, em transferências logísticas no Brasil e no México. O método combina análise documental do business case, evidências das provas de conceito e modelagem determinística por rota e veículo. A série de seis provas documentadas registrou, no Brasil, incremento de 30% na segunda prova e 31,67% na terceira; no México, a segunda atingiu 24,08%. Esses resultados sustentam os parâmetros de 30% e 24% adotados na projeção, preservando as diferenças de veículo, equipe e tempos entre testes. Sobre 17.499.686 pacotes e 1.162 viagens mensais, o modelo estima 239,38 viagens equivalentes evitadas por mês, ou 2.872,59 por ano, com US$ 8.064.447,33 em fretes brutos anuais evitados. Considerando pessoal por horas dedicadas a cada implemento e substituição dos custos atuais de movimentação, o benefício operacional anual projetado é US$ 5.003.360,16 no S1 e US$ 7.622.588,76 no S2, antes do CAPEX. A capacidade foi calculada com três turnos nas origens e dois nos destinos, sete horas úteis por turno e trinta dias mensais. No S2, a demanda utiliza de 19,78% a 98,95% das horas de atendimento dimensionadas por site. As provas de conceito validam a otimização da carga e sustentam o potencial de redução de despachos; os benefícios anuais representam projeções para doze meses estabilizados.

Palavras-chave | Logística; Truckfullness; Carregamento a granel; Produtividade; Custos de transporte.

1. INTRODUCTION

Vehicle space utilization influences the number of trips required to transport a given volume of products. In operations constrained by volumetric capacity, revising the loading method can increase the payload transported without increasing vehicle size. Translating this gain into economic benefits also requires consideration of loading and unloading activities, equipment, product integrity, and operational capacity.

The Truckfullness Loose Load project, identified in the business case with Hélio Ziggiatti as the person responsible, proposes replacing the 4+4 palletized loading method with loose tote transportation on transfer routes [1]. The March 2026 presentation records tests conducted in Brazil and Mexico [2]. The objective of this study is to compare the current method and scenarios S1 and S2, explain the increase in SPR by vehicle type and route, derive the reduction in trip demand, and assess the annual potential of freight and operating costs.

The approach is consistent with waste elimination and work improvement within the Toyota Production System. Toyota emphasizes that technological solutions should originate from an understanding of the process and the reduction of waste and overburden [3]. This theoretical foundation guides the discussion; the values used in the study derive exclusively from the BC and project records, without using external benchmarks to estimate benefits.

2. MATERIALS AND METHODS

2.1 Sources and Scope

The primary source is BC_Truckfullness_Totable_Jun26.xlsx [1], with an analysis of the RE, Inputs, Lane Data, CAPEX, and Dimensionamento worksheets. The project monitoring presentation [7] and reports [9]–[11] document six POCs, three in each country. Tote counts

support the capacity gains of 30% adopted for Brazil and 24% for Mexico in the BC. The March presentation [2] is used as a supplementary summary. The person responsible clarified the units, working hours, and economic scope and reported an additional test using S2 equipment and operating times of 2 hours at each end [4]. These definitions were incorporated into the revised copy [5], preserving the original file. Documented results, personally communicated results, and model projections are identified according to their sources.

The study is applied and descriptive, using documentary analysis and deterministic modeling by route and vehicle type. Reproduction consists of maintaining the volumes and rates of each row, applying SPR gains by country, calculating proposed trips, and converting costs using the BC exchange rate. The comparison uses the same monthly volume across all three methods. Its results represent planning equivalents and economic projections, without statistical inference for a population of trips.

The scope includes totable cargo and 22 combinations of origin, destination, and vehicle type. There are three origins and three destinations in Brazil and one origin and four destinations in Mexico. Gains were measured in SPR, the number of items per vehicle, and in totes by vehicle type, according to the person responsible. The percentage increase is applied to the respective baseline; tote quantities from the tests and package quantities from the BC remain expressed in their respective units. The horizon comprises twelve months of stabilized operations, without volume growth, with all destinations incorporated on the same start date.

2.2 Operational Methods Compared

Table 1. Comparison of Methods and Parameters

Parameter	Current	S1	S2
Loading configuration	4+4 palletized	Loose totes	Loose totes
Reference equipment	Pallet jack	Conveyor and ladder at destination; ladder at origin	Automatic stackers at origin and destination
SPR increase in BR and MX	Reference	30% and 24%	30% and 24%
Operators per team at each end	1	4	2
Loading and unloading per transport unit	40 and 40 min	6 and 4 h	2 and 2 h
Nature of evidence	Documented baseline	BC operational scenario	BC semi-automation scenario

Times are defined per transport unit for the current method as well as for S1 and S2. A double-trailer truck corresponds to two transport units; the remaining vehicles correspond to one. The current method requires 40 minutes to load and 40 minutes to unload each transport unit. S1 uses 6 hours at the origin and 4 hours at the destination, with four operators at each end; S2 uses 2 hours at each end, with two operators in the model. Loading times of 2 hours and unloading times of 2 hours were achieved in a test using S2 equipment at the origin and destination. Personnel costs correspond to the hours effectively dedicated to servicing transport units, rather than the full occupancy of shifts. Capacity considers 30

days per month, 7 productive hours per shift, 3 shifts per day at origins and 2 at destinations, with teams and equipment from the Dimensionamento worksheet.

2.3 SPR Equations and Reduction in Trip Demand

The formulas are applied to each combination of route and vehicle type within the same period. Volume is the monthly number of packages; Trips is the number of monthly dispatches; SPR is the number of packages per trip; CPR is the freight cost per trip in local currency; Exchange Rate is the amount of local currency per dollar. The qualifiers Current and Proposed identify the conditions being compared. SPR Gain = (Proposed SPR / Current SPR) − 1, in decimal form. For aggregated indicators, SPR = Total Volume / Total Trips; the SPR stored by route in the BC is rounded.

$$\text{Current SPR} = \text{Volume} / \text{Current Trips} \quad (1)$$

$$\text{Proposed SPR} = \text{Current SPR} \times (1 + \text{SPR Gain}) \quad (2)$$

$$\text{Proposed Trips} = \text{Volume} / \text{Proposed SPR} \quad (3)$$

$$\text{Proposed Trips} = \text{Current Trips} / (1 + \text{SPR Gain})$$

$$\text{Avoided Trips} = \text{Current Trips} - \text{Proposed Trips} \quad (4)$$

$$\text{Avoided Trips} = \text{Current Trips} \times \text{SPR Gain} / (1 + \text{SPR Gain})$$

$$\text{Trip Reduction (\%)} = [\text{SPR Gain} / (1 + \text{SPR Gain})] \times 100 \quad (5)$$

Therefore, increasing SPR by 30% does not reduce trips by 30%: the theoretical reduction is 23.08%. For an increase of 24%, the reduction is 19.35%. Volume remains constant. Proposed Trips and Avoided Trips are continuous planning equivalents. In actual scheduling, rounding and minimum frequencies must be addressed by route and time window: Proposed Trips = ceiling(Volume / Proposed SPR). The ceiling function rounds upward to the next integer; each annualized component is not rounded individually.

In this study, vehicle reduction means avoided trips or dispatches required to transport the same volume. It does not represent the removal of physical assets from the fleet. If asset sizing is required, the relationship is: Current Fleet = ceiling(Current Trips / Trips per Vehicle); Proposed Fleet = ceiling(Proposed Trips / Trips per Vehicle); Fleet Reduction = Current Fleet − Proposed Fleet. The indicator adopted in the results is Avoided Trips.

2.4 Economic Equations and Handling Costs

$$\text{Current Freight (USD)} = \text{Current Trips} \times \text{CPR} / \text{Exchange Rate} \quad (6)$$

$$\text{Proposed Freight (USD)} = \text{Proposed Trips} \times \text{CPR} / \text{Exchange Rate} \quad (7)$$

$$\text{Avoided Freight (USD)} = \text{Avoided Trips} \times \text{CPR} / \text{Exchange Rate} \quad (8)$$

The Exchange Rate corresponds to units of local currency per dollar: 5.20 BRL/USD and 18.50 MXN/USD, according to Inputs!B18:B19. CPR varies by route and vehicle type. Total Avoided Freight is the sum of Avoided Freight calculated and converted into USD for

each combination; a single average CPR is not applied, nor are different local currencies added together.

$$\text{Current Cost} = \text{Total Current Freight} + \text{Current HC Cost} + \text{Current Equipment Cost} \quad (9)$$

$$\text{Proposed Cost} = \text{Total Proposed Freight} + \text{Proposed HC Cost} \quad (10)$$

$$\text{Monthly Benefit} = \text{Current Cost} - \text{Proposed Cost} \quad (11)$$

$$\text{Monthly Benefit} = \text{Total Avoided Freight} + \text{Current HC Cost} + \text{Current Equipment Cost} - \text{Proposed HC Cost}$$

$$\text{Annualized Benefit} = 12 \times \text{Monthly Benefit} \quad (12)$$

Current Cost and Proposed Cost are comparable monthly costs within the scope of the BC. HC identifies loading and unloading personnel. For each route: Current Transport Units = Current Trips × Transport Units per Trip; Proposed Transport Units = Proposed Trips × Transport Units per Trip. Transport Units per Trip is 2 for double-trailer trucks and 1 for the remaining vehicles. Current HC Cost = Current Transport Units × Current Operators per End × (Current Loading Time + Current Unloading Time) × Hourly Cost / Exchange Rate. Current Operators per End = 1, and the sum of operating times is 80/60 hours. Current Equipment Cost = Current Transport Units × (Current Loading Time + Current Unloading Time) × Monthly Rental / 220 / Exchange Rate, according to the BC allocation.

Proposed HC Cost = Proposed Transport Units × Operators per End × (Loading Time per Transport Unit + Unloading Time per Transport Unit) × Hourly Cost / Exchange Rate. In S1, there are four operators and ten total hours per transport unit; in S2, two operators and four total hours. The rates are 31.36 BRL/h in Brazil and 115 MXN/h in Mexico. Each route is calculated in its own currency and converted into USD before aggregation. Current personnel and pallet jack costs are replaced by proposed personnel costs; investment in new equipment is presented separately. The allocated teams determine available capacity, while costing uses dedicated hours.

Annualized Benefit = 12 × Monthly Benefit, under stabilized operations and with all sites implemented simultaneously. The projection does not apply a ramp-up period, volume growth, or financial discounting. Maintenance, energy, training, systems, damage, and tax effects are not included in the economic scope of this BC. CAPEX is presented separately: the annual operational benefit does not correspond to the net cash flow of the investment.

2.5 Break-Even Point and Minimum CPR

The feasibility analysis compares freight costs associated with avoided trips against the increase in handling costs. The new total cost per trip should not be compared directly with CPR: current costs are replaced, and only a fraction of dispatches is avoided. Volume, SPR Gain, operating times, and scenario resources are maintained; Current CPR and Proposed CPR have the same rate per route. All costs below are monthly and expressed in USD before converting the threshold into local currency.

S1 Incremental Cost = S1 HC Cost − Current HC Cost − Current Equipment Cost (17)

S2 Incremental Cost = S2 HC Cost − Current HC Cost − Current Equipment Cost

Minimum Operational CPR = maximum[0; Incremental Cost × Exchange Rate / Avoided Trips] (18)

Monthly Benefit = Avoided Trips × CPR / Exchange Rate − Incremental Cost (19)

With positive Avoided Trips and positive Incremental Cost, a CPR below the threshold produces an operational loss; at the threshold, the benefit is zero; above it, there is a positive benefit within the scope of the BC. The zero floor in Equation (18) represents the domain of nonnegative rates. The threshold assumes that SPR Gain and the cost structure remain constant when only the rate varies; it does not constitute an experimental extrapolation to new cargo types.

To assess investment recovery over twelve months of stabilized operations, the portion of CAPEX allocated to the route is added to the monthly cost. Allocated CAPEX = Origin CAPEX × Route Share of Origin Transport Units + Destination CAPEX × Route Share of Destination Transport Units. The shares use proposed transport units per month and total 100% at each site, without duplicating investment.

Minimum CPR for Recovery in 12 Months = maximum[0; (Incremental Cost + Allocated CAPEX / 12) × Exchange Rate / Avoided Trips] (20)

Equation (20) requires twelve monthly benefits to cover allocated CAPEX. This represents simple recovery under stabilized operations, without financial discounting, taxes, or costs excluded from the BC. The allocation is analytical for the complete portfolio; isolated implementation on a particular route requires resizing the equipment and investments of the sites involved.

3. RESULTS

3.1 Results and Evolution of the Six Proof-of-Concept Tests

The documentary series comprises six proof-of-concept tests conducted between June 2025 and April 2026, three in Brazil and three in Mexico. The project monitoring presentation [7] consolidates operational records, supplemented by Mexican reports [9], [11] and Brazilian reports [10]. Table 2 organizes the tests by execution date, route, volume, operating times, and personnel. Total time, dock occupancy time, effective time, and net time retain the terminology used in the respective reports; they are not treated as equivalent measurements.

Table 2. Comparative Summary of the Six Documented POCs

POC, Date and Route	Totes / Gain	Loading	Unloading	HC per End	Quality / System
BR 1 — June 30–July 8, 2025 — RC01 → BA01	1,176 / +22.50%	4h01 total	3h18 total; 2h39 effective	Origin: 5; Destination: 4	System and load-securing adjustments; no consolidated numerical quality data in this table
MX 1 — December 16–17, 2025 — MXRC03 → MXNL01	1,304 / +8.67%	4h13 total	4h08 total; 2h37 effective	Origin: 5; Destination: 6	100% decanting; DPMO 2,212; no damage identified
MX 2 — January 13–14, 2026 — MXRC03 → MXNL01	1,489 / +24.08%	5h03 total; 4h effective	Approximately 3h	Origin: 4; Destination: not completed in the initial table	5 totes with deviations; 33 items with errors; no damage identified
MX 3 — March 10–11, 2026 — MXRC03 → MXNL01	1,449 / +20.75%	5h56 total; 4h effective	2h10 at dock	Origin: 4; Destination: 4	Zero deviations and DPMO; 100% decanting; no damage identified
BR 2 — April 9–10, 2026 — RC01 → SP04	1,560 / +30.00%	6h net	6h net	Origin: 2 T1 / 4 T2; Destination: 3 T2	RFID 99.8%; 100% reconciliation; occurrence of 1 HU not physically loaded
BR 3 — April 29–30, 2026 — RC01 → SP04	1,580 / +31.67%	5h39 net	4h10 net	4 per shift/end; shortage of 1 HC for 2h during T2 at destination	RFID 99.62% of tagged totes; no collapse; PGR OK

The number of personnel represents the recorded workforce at each end and shift, without adding teams from successive shifts as though they were working simultaneously. For BR 1, the baseline of 960 totes is preserved from the summary [2]; for the remaining tests, the baseline is 1,200 totes. The increase is calculated as Capacity Gain (%) = (Totes in the POC / Totes in the Baseline − 1) × 100. The indicator demonstrates physical capacity per vehicle; its application to SPR in packages is a projection assumption of the BC, preserving the units of each indicator.



Figure 1. Evolution of capacity gains across the six POCs in chronological order. Percentages are calculated relative to the baseline of each configuration: 960 totes in BR 1 and 1,200 in the remaining tests. Tote counts are test results; SPR gains adopted in the BC are 30% for Brazil and 24% for Mexico. Sources: [2], [7], [9]–[11].

3.1.1 Operational Observations, Quality, and Lessons Learned from Each Test

BR 1 — RC01 → BA01, loading on June 30, 2025, and unloading on July 8, 2025. A total of 1,176 totes were transported, with five people involved in loading and four in unloading. The origin required adjustments to the MU limit at the assembly position and to the Network Container. At the destination, interventions were required regarding timeout, MU status, and decanting. Partial cargo displacement, opportunities to reinforce load securing, heavy totes positioned at elevated heights, low conveyor flow efficiency, and stage-in saturation, which occupied three docks, were recorded. Total unloading time was 3h18, and effective unloading time was 2h39. The specific time study conducted at BA01 divided the latter period into 2h03min29s of estimated processing time and 35min31s of waste; the estimated time is not presented as the observed duration of a new POC [7].

MX 1 — MXRC03 → MXNL01, December 16–17, 2025. A total of 1,304 totes were loaded; the destination table identifies 1,224 loose totes, consistent with maintaining part of the cargo in the 4+4 configuration for containment. Loading lasted 4h13 with five people. Unloading required 4h08 dock-to-dock, including 2h37 exclusively dedicated to unloading, with six people. There was a 1h15 stoppage due to a decanting failure and an additional 16 minutes associated with collapsed totes, personnel rotation, and hydration. The report recorded 100% dispatch and decanting into the correct HU, DPMO of 2,212 attributed to P2M/PA errors, no damage identified, and a calculated ROI of −7.7%. Lessons learned guided revisions to the workflow, containment, and work instructions [7], [11].

MX 2 — MXRC03 → MXNL01, January 13–14, 2026. Transportation of 1,489 totes represented a 24.08% increase over the baseline of 1,200. The table records 5h03 of total loading time and 4h of effective loading time, with four representatives. Unloading was reported at approximately 3h; its HC remained uncompleted in the initial table. The new arrangement eliminated excessive gaps, employed four safety separations, and exceeded the calculated potential by 19 totes. Five totes with deviations, 33 items with P2M/PA errors, and no identified damage were recorded; the reported calculated ROI was 39.9%. The DPMO entry appears as “25,835,” without a denominator allowing independent reconstruction; therefore, the data is preserved literally. The indication of 100% decanting accompanied by “−5 versus target,” questioned within the email thread itself, is not used as additional evidence of perfect quality [7], [9], [11].

MX 3 — MXRC03 → MXNL01, March 10–11, 2026. A total of 1,449 totes were transported, equivalent to 20.75% above the baseline. Loading required 5h56 in total and 4h effectively; unloading required 2h10, with four people at each end. The reports associate the lower capacity compared with the previous POC with smaller vehicle dimensions and the space occupied by restraints. Personnel changes during breaks increased the total duration. Zero totes with deviations, zero DPMO, 100% dispatch and decanting into the correct HU, and no identified damage were recorded. The SHE/ergonomics plan was reported as validated, while LP validation remained in progress at the time. The year of the test is identified by the communication dated March 2026, despite the “10/03/25” entry in the table [7], [9], [11].

BR 2 — RC01 → SP04, April 9–10, 2026. A total of 1,560 totes were transported, exactly 30% above the 1,200 totes of the 4+4 standard. Net loading and unloading times were 6h at each end. The table records two HCs in T1 and four in T2 at the origin, and three in T2 at the destination, with personnel shortages affecting the workflow. The supplementary report recorded readings of 1,557 of the 1,560 totes, or 99.8%, and 100% HU reconciliation. There was an initial reading problem and a delay in updating HUs on the handheld scanner. The presentation records one HU dispatched within the system but not physically; this occurrence is preserved separately from the aggregated reconciliation indicator. Tilting of the final walls and falling totes during unloading also occurred. There was no PGR exceedance; the table reports no identified damage [7], [10].

BR 3 — RC01 → SP04, April 29–30, 2026. A total of 1,580 totes were transported, or 31.67% above the baseline; the report presents the rounded gain as 31.6%. Net operating times were 5h39 for loading and 4h10 for unloading. The table specifies four people per shift at both ends and records a shortage of one person for two hours during T2 at the destination. There was no tote collapse, with the use of wood and ropes, nor any PGR exceedance. Stacking equipment, alternative layouts, and workflows were tested with MTM monitoring. The RFID report counted 1,568 tagged totes and 1,562 read by the portal: a 99.62% reading rate among tagged totes, 99.24% tag coverage, and 98.86% identification relative to the 1,580 physical totes. Tagging occurred at the origin, and the start of unloading was delayed. The initial tables refer DPMO, damage, and decanting quality/time to specific monitoring activities; zero values are not assigned to indicators without consolidated numerical results [7], [10].

3.1.2 Controlled Indicators and Interpretation Criteria

Table 1. Indicators Monitored Across the Six POCs and the Project

Dimension	Controlled Indicators	Records and Scope
Capacity	Total MUs/totes; increase over 4+4; SPR	Totes observed during tests; SPR in packages projected in the BC
Time	Loading; unloading; waiting; decanting; dock occupancy	Distinction between total, effective, and net duration, preserving the scope of each report
Personnel and productivity	HC per end/shift; availability; totes per person and per labor-hour	Records of personnel shortages and HC changes; productivity disclosed in the BR 3 report
Quality	DPMO; items with errors; totes with deviations; damage	Separate tote deviations and item errors; no identified damage refers to the observed cargo
Traceability	Physical/system dispatch; receiving; HU reconciliation	Verification of physical loading, system status, decanting, and scanner updates
RFID	Tag coverage; totes read; reading rate	Separate denominators: physical total, tagged totes, and identified totes
Safety and ergonomics	Containment; stability; posture; effort; equipment; MAC assessment	Operational observations and ergonomic assessment by function, with proposed controls
Transportation and economics	PGR; CPI; CPR; avoided trips; ROI; break-even point	PGR monitored during Brazilian tests; other metrics have specific test or projection scopes
Team management	Absenteeism during dispatch/ receiving; rotation between functions	Indicator planned within the project; reports record absences and replacements without a percentage series per POC

Indicator availability differed across tests. Tote counts, operating times, and HC form the comparative operational basis; quality, reconciliation, and RFID follow the scopes and denominators specified in each report. The Mexican tables also display OBN within the 06:00–14:00 window, with values of 3.2 and 5.6 in MX 2 and MX 3, without a defined unit in the material. These figures are recorded as supplementary information, without interpretation as productivity or a causal relationship with the gains. The Mexican ergonomic assessment used the MAC tool and biomechanical analysis, with results by function and proposed controls. The indication of no identified damage describes the observed cargo and does not replace risk analysis and assessment of working conditions [7], [9]–[11].

3.1.3 Relationship Between Experimental Results and BC Parameters

The increases adopted in Inputs!B26:B27 of the BC have documentary support in the POC counts: Brazil achieved 30% in BR 2, exceeded by 31.67% in BR 3; Mexico achieved 24% in MX 2, whose calculated result was 24.08%. These values are not universal minimums across all tests: MX 1 achieved approximately 8.67%, and MX 3 achieved 20.75%, under different vehicle and execution conditions. In this article, 30% and 24% identify the parameters selected for the projected scope rather than an invariant capacity for any configuration.

The highest occupancy occurred in BR 3 and MX 2. The shortest total loading times occurred in BR 1 (4h01, five people) and MX 1 (4h13, five people), with cargo and teams different from those in the highest-occupancy tests. The shortest Brazilian unloading time recorded in total duration occurred in BR 1 (3h18; 2h39 effective); the shortest Mexican unloading time occurred in MX 3 (2h10). Therefore, highest occupancy, shortest duration, and lowest personnel requirements are not interchangeable results, nor do they constitute a single configuration obtained by combining the best values from different tests.

S1 uses four operators per end and operating times of 6h for loading and 4h for unloading per transport unit in the BC; these are planning parameters, distinct from the 4h/3h test targets and the observed times in each execution. For S2, the person responsible for the project reports an additional test with equipment at both ends, during which loading and unloading times of 2h each were achieved [4]. This test is presented as experimental evidence communicated by the person responsible, separately from the series of six POCs supported by reports. The S2 model maintains two operators per end. Capacity assessment across the entire network is calculated in Section 3.7.

Applying Avoided Trips = Current Trips × SPR Gain / (1 + SPR Gain), the documented parameters selected in the BC support a projected reduction of 23.08% in Brazilian dispatches and 19.35% in Mexican dispatches, at constant volume. The tests validate increased cargo transported per vehicle and the mechanism for reducing trip requirements. The financial projection applies this mechanism to route volumes and rates, without presenting annual values as savings already realized.

3.2 Baseline Volumes and Rates

Table 3. Aggregated Monthly Baseline by Country [1]

Country	Packages/Month	Trips/Month	Weighted SPR	Freight/Month USD
BR	7,610,713	389	19,564.81	US$1,666,944.69
MX	9,888,973	773	12,792.98	US$1,484,681.62
Total	17,499,686	1,162	15,059.97	US$3,151,626.31

The annualized current freight cost is US$37,819,515.74. The baseline volume is 17,499,686 packages per month, equivalent to 209,996,232 packages over twelve months without growth. Average SPR is weighted by the number of trips; it is not a simple average of indicators from different routes. The complete list of volumes and rates is presented in Appendix A.

3.3 SPR by Vehicle and Route

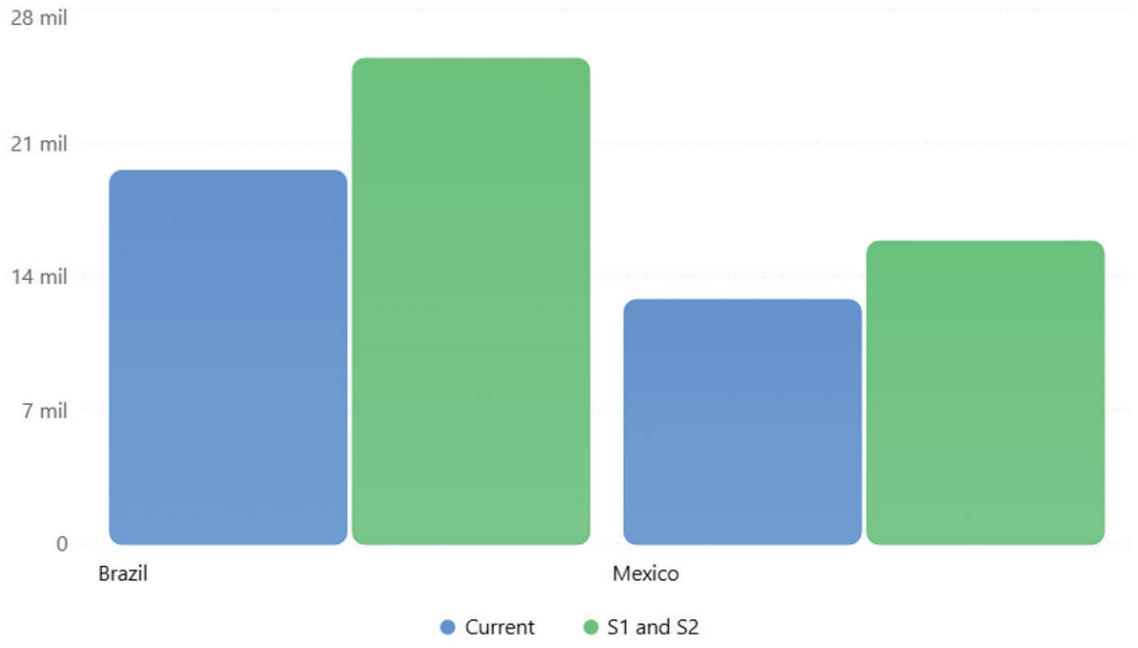

Figure 2. Aggregated SPR by country using BC parameters: Brazil 30%, achieved in BR 2 and exceeded in BR 3; Mexico 24%, supported by the 24.08% achieved in MX 2. S1 and S2 share these gains in the model. Sources: [1], [5], [7].

The absolute increase in SPR depends on the route and vehicle type. For example, BRRC01–BRBA01 using a double-trailer truck increases from 23,090 to 30,017 packages per trip (+6,927; +30%). MXRC03–MXGT01 increases from 11,596 to 14,379.04 (+2,783.04; +24%). Values for all combinations are presented in Appendix B.

3.4 Avoided Trips and Projected Freight Costs

Table 4. Monthly and Annual Operating Projections [1]

Country	Current/Month	S1 or S2/Month	Avoided/Month	Avoided Freight/Year
BR	389.00	299.23	89.77	US$4,616,154.53
MX	773.00	623.39	149.61	US$3,448,292.80
Total	1,162.00	922.62	239.38	US$8,064,447.33

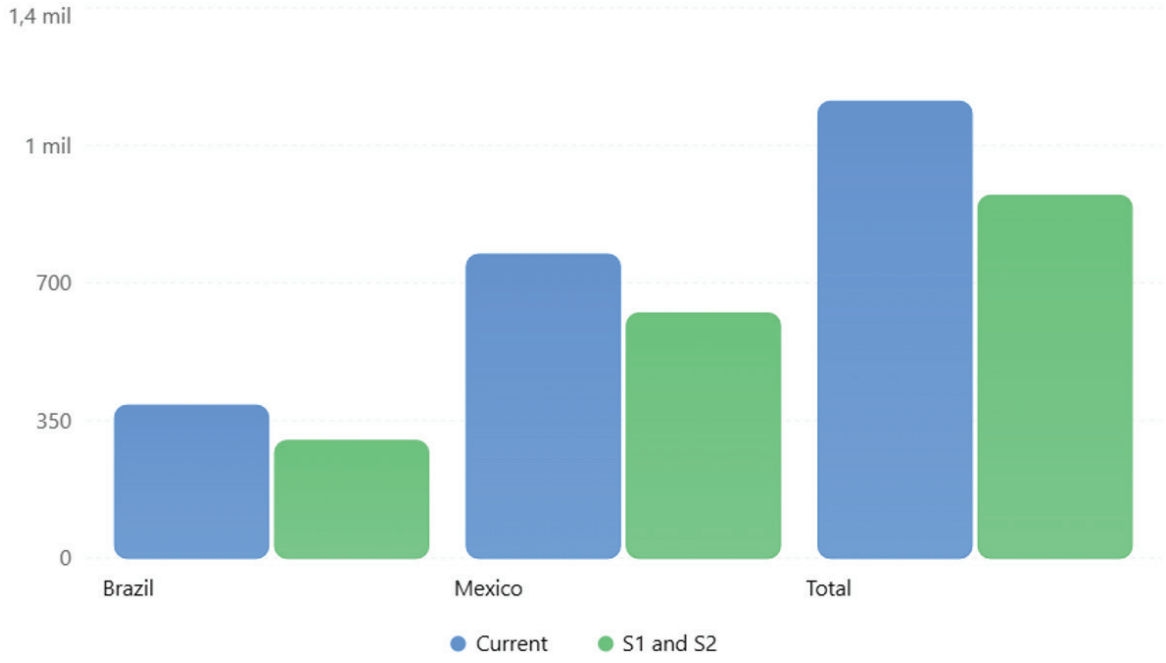

Figure 3. Monthly trip demand at constant volume. S1 and S2 present the same number of trips in the model.

Overall, the projection corresponds to 20.60% fewer trips, 2,872.59 equivalent avoided trips per year, and US$8,064,447.33 in avoided gross freight costs. Remaining freight costs amount to US$29,755,068.42 per year. These values are calculated expectations, not freight costs already avoided or a demonstrated reduction in physical trucks.

3.5 Economic Comparison of the Three Methods

Table 5. Comparable Monthly Costs in USD

Component	Current	S1	S2
Freight	US$3,151,626.31	US$2,479,589.03	US$2,479,589.03
Handling personnel	US$11,512.90	US$272,836.31	US$54,567.26
Replaceable current equipment	US$6,232.82	—	—
Comparable total operational cost	US$3,169,372.03	US$2,752,425.35	US$2,534,156.30
Monthly benefit versus current	—	US$416,946.68	US$635,215.73
Annualized benefit versus current	—	US$5,003,360.16	US$7,622,588.76

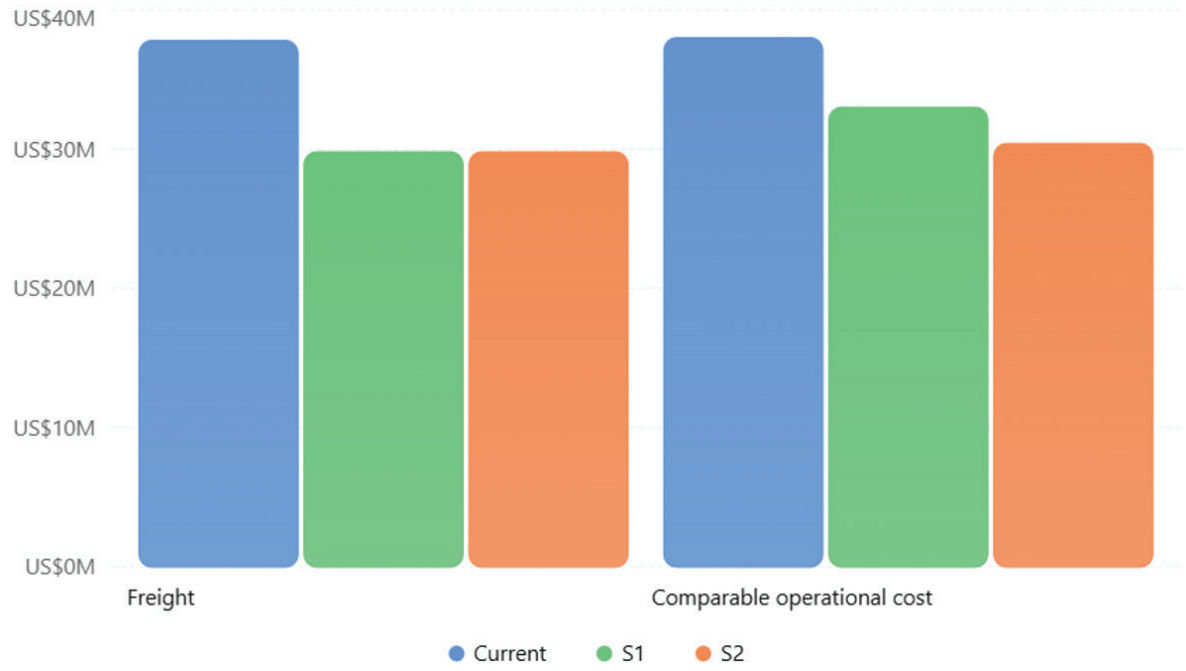

Figure 4. Freight and comparable operational costs for twelve months of stabilized operations. Costs include dedicated hours per transport unit. CAPEX and expenses expressly excluded from the BC scope are presented separately.

S2 presents a projected operational benefit exceeding S1 by US$2,619,228.59 annually, due to the combination of shorter handling times and fewer operators per end. The scenarios share the same SPR and freight gains. The operational benefit already incorporates avoided freight costs, preventing double counting. The results represent projections for the complete scope.

3.6 Investment and Sensitivity

Table 6. Investment for the Complete Scope

Indicator	S1	S2
Total CAPEX for the complete scope	US$699,400.42	US$360,000.00
Amortization period	60 months	60 months
Reference annual amortization	US$139,880.08	US$72,000.00
Implementation scope	All sites at the beginning	All sites at the beginning

CAPEX considers all locations from the beginning, including BRPE01 and MXYU01. The quantity of equipment derives from the teams required for each scenario: S1 requires 12 sets at origins and 14 at destinations; S2 requires five sets at origins and seven at destinations, with two stackers per set, totaling 24 pieces of equipment. CAPEX is US$699,400.42 in S1 and US$360,000.00 in S2 under the average-flow scenario. Reference amortization is 60 months and is not deducted from the operational benefits presented in Table 5.

Table 7. Sensitivity to SPR Increases in Brazil

BR Gain	Avoided/Month	Gross Freight/Year	S1 Benefit/Year	S2 Benefit/Year
22.5%	221.06	US$7,122,374.97	US$3,974,717.40	US$6,663,202.32
25.0%	227.41	US$7,448,960.06	US$4,331,313.55	US$6,995,789.62
30.0%	239.38	US$8,064,447.33	US$5,003,360.16	US$7,622,588.76

The main projection uses 30% for Brazil and 24% for Mexico. The sensitivity analysis maintains Mexico at 24% and changes only the Brazilian increase, recalculating trips, freight costs, and dedicated personnel hours. Rates, hourly costs, current costs, and available teams remain constant. The 22.5% represents the first Brazilian POC, and 25% represents an intermediate reference; both are comparisons with the main projection of 30%.

3.7 Service Capacity by Origin and Destination

Teams were sized separately for each scenario based on required service hours and available productive hours. Under average flow, S1 requires 12 parallel teams at origins and 14 at destinations; S2 requires five at origins and seven at destinations.

Required Teams = ceiling[Proposed Transport Units per Month × Service Time per Transport Unit / (Days per Month × Shifts per Day × Productive Hours per Shift)].

A team represents a parallel service set per shift, with personnel and equipment, rather than the total number of people across different shifts. S1 uses four operators per set; S2 uses two. Costing remains based on dedicated hours. Origins operate three shifts and destinations two, with seven productive hours per shift and thirty days per month. Planning increases are applied to the flow before rounding the number of teams.

Transport Units per Shift = Proposed Transport Units per Month / (Days per Month × Shifts per Day) (13)

Required Hours = Proposed Transport Units per Month × Service Time per Transport Unit (14)

Available Hours = Parallel Teams × Days per Month × Shifts per Day × Productive Hours per Shift (15)

Capacity Utilization (%) = Required Hours / Available Hours × 100 (16)

In S2, Service Time per Transport Unit = 2h at each end. BRRC01 receives 303.08 transport units/month, requiring 606.15 service hours. One team × 30 days × 3 shifts × 7 hours provides 630 hours/month: utilization of 96.21%. In MXRC03, 1,246.77 hours require two teams, providing 1,260 hours, with utilization of 98.95%. Double-trailer trucks count as two transport units for servicing and one trip for freight rates.

S2 Origins — BRRC01: one team, 606.15/630h (96.21%); BRRC02: one, 246.15/630h (39.07%); BRRC03: one, 124.62/630h (19.78%); MXRC03: two, 1,246.77/1,260h (98.95%).

Total: five teams, 2,223.70 required hours and 3,150 available hours. In S1, the same origins require three, two, one, and six teams, respectively, totaling 12.

S2 Destinations — each site requires one team. BRBA01: 341.54/420h (81.32%); BRPE01: 276.92/420h (65.93%); BRSC02: 358.46/420h (85.35%); MXGT01: 379.03/420h (90.25%); MXJC01: 274.19/420h (65.28%); MXNL01: 343.55/420h (81.80%); MXYU01: 250.00/420h (59.52%). Total: seven teams, 2,223.70 required hours and 2,940 available hours. In S1, each destination requires two teams, totaling 14.

All sites accommodate the projected average flow with the calculated teams. In S2, maximum utilization is 98.95% at MXRC03 and, among destinations, 90.25% at MXGT01. In S1, maximum utilization is also 98.95% at origins and 90.25% at destinations, with a larger number of teams due to longer operating times. Therefore, the longer individual operating time fits within the capacity sized for average operations. For increases in demand, the BC recalculates teams and investment in the planning scenarios, without assuming the same spare capacity as in the previous configuration.

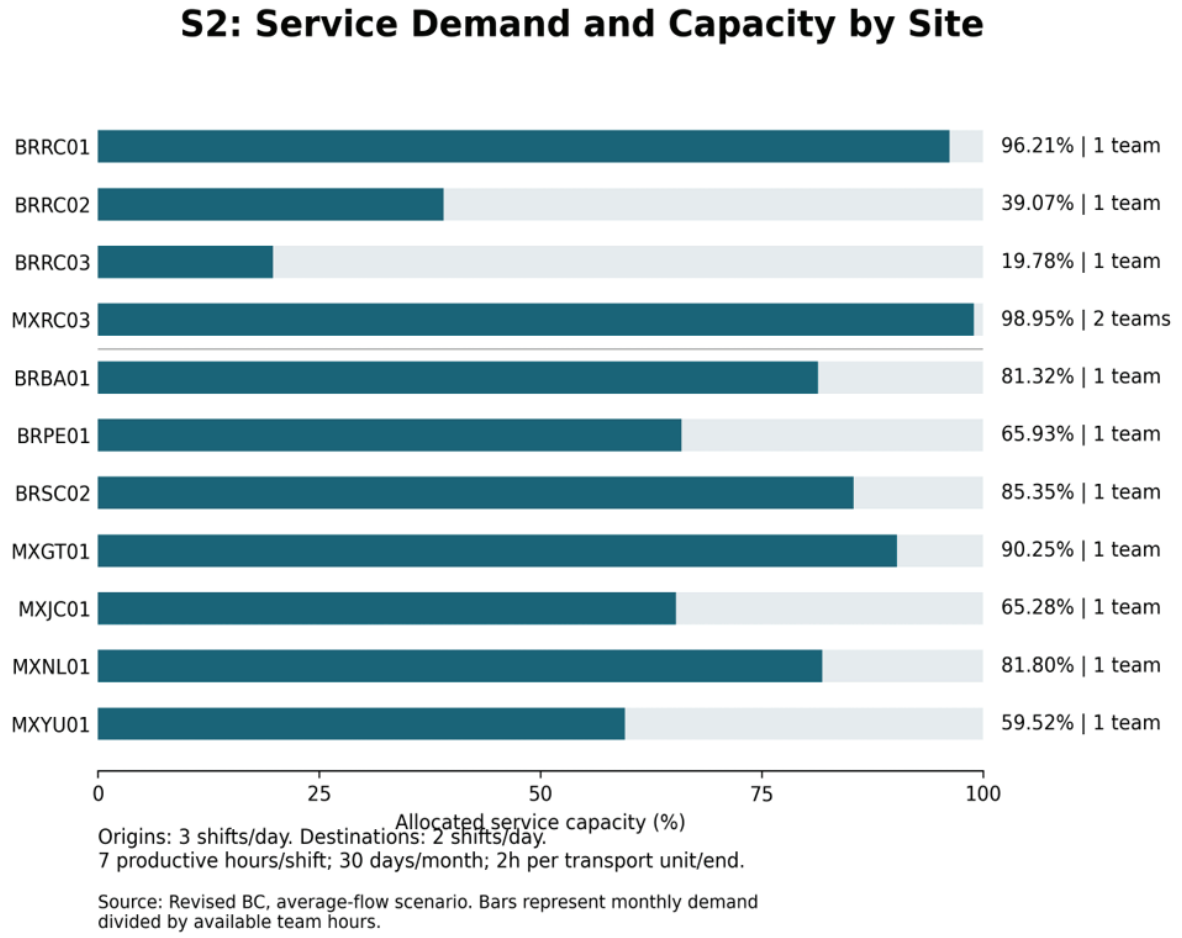

Figure 5. Service capacity utilization in S2 by site. Source: revised copy of the BC [5]. Origins operate three shifts and destinations two; seven productive hours per shift and thirty days per month.

3.8 CPR Thresholds and Loss of Feasibility

Table 8 presents the minimum operational CPR calculated using gains of 30% in Brazil and 24% in Mexico. The threshold is expressed in the same currency and unit as the contracted rate: value per trip. With the unit costs of the BC, operational thresholds are identical for routes within the same vehicle family and country because monthly volume cancels out when incremental costs are divided by avoided trips. For double-trailer trucks, servicing two transport units doubles the cost and threshold relative to Brazilian semitrailers.

Table 8. Minimum Operational CPR by Vehicle Family

Country	Vehicle	Currency	Minimum CPR S1	Minimum CPR S2
Brazil	Double-trailer truck	BRL	7,737.66	1,047.52
Brazil	Semitrailer	BRL	3,868.83	523.76
Brazil	Extended semitrailer	BRL	3,868.83	523.76
Mexico	Mexican semitrailer	MXN	18,061.31	2,727.98

All 22 route and vehicle combinations in the BC have CPR values above the operational threshold in S1 and S2. The threshold closest to the current rate in S1 occurs on MXRC03–MXGT01: CPR of MXN 20,730.00 compared with a minimum of MXN 18,061.31, allowing a reduction of 12.87% before reaching operational break-even. In Brazil, BRRC03–BRSC02 using a double-trailer truck presents CPR of BRL 9,772.56 compared with the S1 minimum of BRL 7,737.66, allowing a reduction margin of 20.82%. The margin is calculated as 1 − Minimum CPR / Current CPR; it does not correspond to a profit margin on revenue.

In S2, lower minimum values result from reduced handling hours and personnel. On MXRC03–MXGT01, the S2 operational minimum is MXN 2,727.98; for the Brazilian double-trailer truck, BRL 1,047.52. These results demonstrate how increased operating costs can offset transportation gains when the rate is low, even while maintaining the physical SPR gain.

CAPEX recovery within twelve months establishes an additional criterion. For MXRC03–MXGT01 in S1, the minimum is MXN 23,008.58, exceeding the current rate of MXN 20,730.00. The route continues to generate an operational benefit of US$6,561.20 per month, but US$78,734.41 over twelve months does not cover the US$145,959.54 in CAPEX allocated to it. Therefore, failure to recover investment within twelve months does not equate to an operational loss. In S2, the recovery threshold for this route is MXN 4,363.09, below the current CPR. For the remaining 21 combinations, S1 recovers the allocated share within twelve months; S2 meets the criterion in all 22 combinations under the model conditions.

Calculations by route, incremental costs, investment allocation, and distance from the thresholds are available in the Viabilidade CPR worksheet of the copy [5]. The sum of allocated investments reconciles with US$699,400.42 in S1 and US$360,000.00 in S2. Algebraic validation applied CPR values 1% below, equal to, and 1% above the break-even point to the four vehicle families and both scenarios, obtaining negative, zero, and positive results, respectively.

4. DISCUSSION

The proof of concept provides operational evidence that the method optimizes cargo loading: the tested vehicles transported more totes than in the reference palletized configuration. The inverse relationship between capacity per trip and trip demand supports the potential reduction in dispatched vehicles at constant volume. The economic projection extends this mechanism to the set of routes in the BC, with their respective volumes, rates, and SPR assumptions. Physical validation of optimization and the potential reduction in dispatches is distinct from measuring realized financial benefits and the number of physical assets no longer required. Maximum weight, stability, minimum frequency, and dock capacity must be respected during implementation.

The analysis demonstrates that S2 accommodates average monthly flow with five parallel teams at origins and seven at destinations. Utilization ranges from 19.78% to 98.95% at origins and from 59.52% to 90.25% at destinations. Longer individual operating times do not generate a deficit in service hours under these operating conditions. Minimum resource sizing presents limited spare capacity at the MXRC03 origin; scenarios involving increased demand recalculate required resources rather than assuming nonexistent reserves.

The capacity conclusion refers to average monthly flow distributed across the defined operating days and shifts. Utilization measures required service hours relative to the available hours of allocated teams; it is not an experimental measurement of queues or occupancy of all docks. Dispatch scheduling must distribute flow across these windows and preserve the simultaneous availability of personnel and equipment. The increase scenarios in the Dimensionamento worksheet are planning factors, without interpretation as observed statistical percentiles.

Freight trips and transport units requiring service are distinct units. In Brazil, the 389 current contractual trips correspond to 635 transport units because each double-trailer truck requires service for two transport units. Freight projections use trips; handling costs and capacity use transport units. This distinction ensures consistency between contractual rates and operational effort.

Regarding fleet reduction, the demonstrable result is the reduced need for dispatches at constant volume. Fewer contracted trips may reduce avoidable costs even without reducing owned assets. Removing trucks from a fleet requires additional analysis of utilization and contracts. Emission reductions are likewise not calculated without route-specific distances, fuel types, and consumption.

4.1 Interpretation Criteria and Economic Scope

The results are reproducible in the revised copy [5]. S1 Benefit = Avoided Freight + Current HC + Current Equipment − S1 HC; S2 Benefit applies the same expression using S2 HC. The calculation incorporates operating times per transport unit, the number of operators at each end, and dedicated hours. The RE summary is linked to route totals, with reconciliation between monthly and annual values.

The selected horizon is twelve months of stabilized operations, without ramp-up, growth, inflation, or discounting. The results do not constitute NPV, IRR, or net cash flow during the first year of implementation. The monetary scope comprises the set of totable routes detailed in the June BC, with the parameters consolidated in this article; values from presentations covering other scopes are not added.

The economic scope includes freight, personnel based on dedicated hours, and replacement of current pallet jack costs, with CAPEX presented separately. Maintenance, energy, training, systems, damage, and tax effects are excluded from the BC by definition of its scope. Therefore, projected operational benefit refers to the difference between explicitly compared costs rather than the total cost of equipment ownership.

The contribution of the study lies in connecting physical evidence of increased transported capacity, calculated reductions in trip demand, and route-specific economic projections. Post-implementation monitoring may compare the results with actual volumes, operating times, resource availability, and costs, maintaining the same units and scope of comparison.

4.2 Lean Logistics: Value Chain Perspective and Assessment of Trade-Offs

The application of Lean Logistics requires defining the unit of analysis as the complete flow that serves the customer. Value stream mapping integrates materials and information and enables assessment of the effects of a change beyond each isolated process [6]. In the case studied, this perspective connects cargo preparation, loading, transportation, receiving, decanting, and product availability. A cost reduction at one stage represents an improvement to the system only when its effects on other stages and customer service are considered.

Truckfullness highlights a trade-off that an assessment restricted to docks might reject. Changing to loose loading increases personnel requirements and processing hours at the origin and destination relative to the palletized method. The tests also record waiting periods, interruptions, and longer vehicle occupancy times, with operational and systemic causes [7]. Under local productivity and service-time indicators, part of the performance deteriorates. Simultaneously, transporting more items per trip reduces the number of dispatches required to accommodate the same volume. Additional handling costs may therefore be offset by a greater reduction in transportation costs.

This relationship is explicitly stated in the business case: Chain Benefit Within the BC Scope = Avoided Freight − Increase in Handling Costs. Within the stabilized horizon analyzed, US$8.06 million in annual avoided gross freight costs results in projected operational benefits of US$5.00 million in S1 and US$7.62 million in S2, after replacing current handling costs and before CAPEX [5]. Thus, the project may benefit the company even while consuming more resources at both ends. The values represent the economic scope declared in the study; they do not, by themselves, demonstrate improvement in total lead time or all supply chain indicators.

The increase in local operating times remains an opportunity for improvement. A comprehensive perspective guides where additional effort is economically justified and where it must be reduced. Standardization, balancing between shifts, team availability, system stability, and supporting equipment should reduce waiting periods, effort, and interruptions without losing gains in transported capacity. Implementation criteria combine economic benefits with service capacity, quality, safety, and customer service commitments. Higher vehicle occupancy must also respect the required dispatch frequency, avoiding cargo consolidation at the expense of additional inventory and waiting time.

Scope selection is a central component of the solution. The project was directed toward distant destinations with high freight costs, for which avoiding a trip tends to offset additional loading and unloading work [7]. Distance serves as guidance for initial selection; the decision is confirmed by actual CPR, SPR gains, volumes, and capacity at both ends. Minimum CPR equations demonstrate that the same physical solution may generate benefits on one route and losses on another. Therefore, its application is not universal: the appropriate method depends on the conditions of each flow. The decision also distinguishes coverage of operational costs from investment recovery within the selected period.

In this context, professional seniority is reflected in the ability to recognize interdependencies, expand the boundaries of analysis, and quantify trade-offs before defining the solution. It requires identifying which local indicators may deteriorate, how much this costs, who absorbs the effort, and under which conditions the combined result remains favorable. The decision should be developed collaboratively with Operations, Transportation, Engineering, Technology, Finance, and quality and safety departments. Shared indicators and responsibilities enable a decision beneficial to the company to be understood and sustained by the teams executing the new process.

Respect for people remains a requirement of transformation. Toyota associates competitiveness with the participation of people working at the gemba, employee development, and improvement of working conditions [8]. In this case, records of “no damage identified” in certain tests represent observations made on that particular cargo; they do not establish a universal absence of risk [7]. Ergonomics, cargo containment, traceability, and quality require specific controls. Financial gains should finance and guide improvements to the method, with operators participating in identifying difficulties, conducting tests, and standardizing solutions.

The managerial contribution of the case is to demonstrate that improvement must be assessed according to its contribution to the complete value stream. The ability to accept, quantify, and reduce a local burden when it enables a demonstrable global benefit and respects customer and personnel requirements constitutes a relevant competency for logistics transformation. Mature decision-making combines a systemic perspective with execution discipline: selecting appropriate routes, making additional costs visible, and continuously improving work at both ends.

5. CONCLUSIONS

The series of six documented POCs validated the increase in transported capacity and supports the potential reduction in dispatches. In Brazil, BR 2 recorded 1,560 totes compared with 1,200 in the baseline (+30%), and BR 3 reached 1,580 (+31.67%). In Mexico, MX 2 transported 1,489 totes compared with 1,200 (+24.08%). These counts support the BC parameters of 30% and 24%, preserving the variation among tests. Applied to 17,499,686 packages and 1,162 monthly trips, the parameters reduce demand to 922.62 equivalent trips/month, with the potential to avoid 2,872.59 annual trips and US$8,064,447.33 in gross freight costs per year.

S1 and S2 share the same transportation capacity and reduction in trips. Handling costs differentiate the projected operational benefits: US$5,003,360.16 annually in S1 and US$7,622,588.76 in S2, before CAPEX of US$699,400.42 and US$360,000.00, respectively. Investment was recalculated according to the teams required for each scenario; personnel costs remain based on dedicated hours per transport unit.

With three shifts at origins and two at destinations, seven productive hours per shift, and thirty days per month, S2 accommodates the average flow with five teams at origins and seven at destinations. Utilization by site ranges from 19.78% to 98.95%. Increased-demand scenarios determine additional team and equipment requirements. The optimization validated in the proof-of-concept tests supports the potential for avoided trips, and the economic horizon corresponds to twelve months of stabilized operations with the entire scope implemented. Monitoring should maintain SPR, trips, service hours, and cost indicators by route.

Feasibility also depends on freight rates. The minimum operational thresholds are BRL 7,737.66 in S1 and BRL 1,047.52 in S2 for Brazilian double-trailer trucks; BRL 3,868.83 and BRL 523.76 for Brazilian semitrailers; and MXN 18,061.31 and MXN 2,727.98 for Mexican semitrailers. All analyzed routes exceed these minimum thresholds. Investment recovery within twelve months is an additional criterion: MXRC03–MXGT01 in S1 remains operationally positive but does not recover the portion of CAPEX allocated to the route within that period.

From the perspective of Lean Logistics, the case demonstrates that supply chain gains can coexist with greater resource consumption and longer operating times at both ends. The implementation decision depends on the comparison between avoided freight costs and additional handling costs, the minimum CPR by route, and the preservation of capacity, quality, safety, and customer service. Professional seniority contributes to defining the scope, making trade-offs explicit, and mobilizing the departments involved. The method should be directed toward flows whose economic and operational conditions support it, while maintaining continuous improvement in the work performed by those responsible for loading and unloading vehicles.

REFERENCES

[1] Mercado Livre. *BC_Truckfullness_Totable_Jun26.xlsx*. Internal business case spreadsheet, last modified October 15, 2026. Worksheets: RE, Inputs, Lane Data, CAPEX, and Dimensionamento. Available at: https://drive.google.com/file/d/1VLULGT2wcK2JlQEg1wUEyvLTrWgEK7hu/view. Accessed: October 29, 2026. Unpublished internal document provided by the author.

[2] Mercado Livre. *CI Projects Truckfullness Loose Load*. Internal project presentation, March 2026. Available at: https://drive.google.com/file/d/1CBWMWem8H5YAiwm8OIp1J6LKBGQVLM53/view. Accessed: October 29, 2026. Unpublished internal document provided by the author.

[3] Toyota Motor Corporation. *Toyota Production System*. n.d. Available at: https://global.toyota/en/company/vision-and-philosophy/production-system/. Accessed: October 29, 2026.

[4] H. J. Ziggiatti Silva. Personal communications concerning operating times per transport unit, staffing requirements at each operational end, working hours, and economic scope, October 29, 2026. Additional communication confirming a test conducted with S2 equipment at both origin and destination, involving two hours of loading and two hours of unloading, November 10, 2026. The S2 test was reported by the project manager; no supporting documentary report was included in the materials provided. Unpublished personal communications.

[5] H. J. Ziggiatti Silva. *BC Truckfullness — Cópia revisada — Horas por implemento* [BC Truckfullness — Revised Copy — Hours per Transport Unit]. Internal calculation spreadsheet, October 29, 2026. Derived from the business case described in Reference [1], incorporating working hours and operational parameters provided through the personal communications described in Reference [4]. Available at: https://docs.google.com/spreadsheets/d/1g4MvQ7CKrcXOTfFVoyrv9TPeIJT-2_oBE5RgucTDF00/edit. Accessed: October 29, 2026. Unpublished project document.

[6] Lean Enterprise Institute. *Value Stream Mapping*. n.d. Available at: https://www.lean.org/lexicon-terms/value-stream-mapping/. Accessed: November 10, 2026.

[7] Mercado Livre. *Granel MWH: Truckfullness Totable MWH*. Internal project monitoring presentation, last modified July 27, 2026. Available at: https://docs.google.com/presentation/d/1XJWOeCjD5zMu0xxttNVkT82Tssp9kY4N/edit. Accessed: November 10, 2026. Unpublished internal document provided by the author.

[8] Toyota Motor Corporation. *People Working at Toyota (Own Workforce)*. n.d. Available at: https://global.toyota/en/sustainability/esg/workforce/. Accessed: November 10, 2026.

[9] Mercado Livre. *E-mail de Mercadolibre SRL — Nuevas Pruebas Loose Load MXRC03_MXNL01*. Internal email correspondence and test data tables concerning operational trials conducted in Mexico, December 2025–March 2026. PDF compilation. Available at: https://drive.google.com/file/d/1Km9JohMk1vkSltObCfg_rz80oH5pBt1_/view. Accessed: November 11, 2026. Unpublished internal correspondence provided by the author.

[10] Mercado Livre. *E-mail de Mercadolibre SRL — POC 2 BR — Loose Load Totable com RFID — RC01_SP04*. Internal email correspondence and technical reports concerning the second and third proof-of-concept (POC) tests conducted in Brazil, April–May 2026. PDF compilation. Available at: https://drive.google.com/file/d/1SVRz3s0SWZqK9J8rL4aGnJQYUJt5Lw1g/view. Accessed: November 11, 2026. Unpublished internal correspondence provided by the author.

[11] Mercado Livre. *E-mail de Mercadolibre SRL — [Importante] Prueba — Loose Load*. Internal email correspondence concerning proof-of-concept (POC) tests conducted in Mexico, December 2025–March 2026. PDF compilation. Available at: https://drive.google.com/file/d/1-wZUcHapEizQNZPbbIB-2xET3WEvxQwg/view. Accessed: November 11, 2026. Unpublished internal correspondence provided by the author.

BIOGRAPHY

Hélio João Ziggiatti Silva is Mechanical Production Engineer holding a degree from Universidade Paulista (UNIP), Brazil. His studies focus on production engineering, logistics, operational efficiency, transportation capacity optimization, and operational cost reduction, with an emphasis on the application of Lean Logistics principles and continuous improvement in logistics processes.

Hélio João Ziggiatti Silva é Engenheiro de Produção Mecânica, graduado pela Universidade Paulista (UNIP). Desenvolve estudos voltados à engenharia de produção, logística, eficiência operacional, otimização da capacidade de transporte e redução de custos operacionais, com ênfase na aplicação dos princípios do Lean Logistics e na melhoria contínua dos processos logísticos.

APPENDIX A — VOLUMES AND RATES BY ROUTE AND VEHICLE

Source [1], Lane Data!A5:I26. CPR is expressed in local currency per trip; it is not the cost per package. Monetary totals are calculated after currency conversion. Location codes are preserved to enable reproduction.

Table A1. Baseline Best regards

Row	Origin > Destination	Vehicle	Packages/ Month	Trips	CPR BRL	Freight USD/ Month
9	BRRC01 > BRBA01	Double-trailer truck	1,570,089	68	30,628.13	400,521.70
10	BRRC01 > BRBA01	Semitrailer	55,265	4	20,269.98	15,592.29
11	BRRC01 > BRPE01	Double-trailer truck	896,159	40	38,922.66	299,405.08
12	BRRC01 > BRPE01	Semitrailer	366,317	28	27,474.79	147,941.18
13	BRRC01 > BRSC02	Double-trailer truck	1,240,947	51	9,914.18	97,235.23
14	BRRC01 > BRSC02	Semitrailer	268,402	18	5,764.30	19,953.35
15	BRRC01 > BRSC02	Extended semitrailer	402,054	26	5,567.03	27,835.15
16	BRRC02 > BRBA01	Double-trailer truck	561,877	26	31,793.86	158,969.30
17	BRRC02 > BRBA01	Semitrailer	51,867	4	21,323.08	16,402.37
18	BRRC02 > BRPE01	Double-trailer truck	453,254	22	35,895.01	151,863.50
19	BRRC02 > BRPE01	Semitrailer	25,780	2	29,807.70	11,464.50
20	BRRC02 > BRSC02	Double-trailer truck	676,652	28	10,632.37	57,251.22
21	BRRC02 > BRSC02	Semitrailer	30,276	2	6,612.85	2,543.40
22	BRRC03 > BRBA01	Double-trailer truck	99,762	5	27,460.73	26,404.55
23	BRRC03 > BRBA01	Semitrailer	228,692	16	21,336.42	65,650.52
24	BRRC03 > BRPE01	Semitrailer	290,720	26	26,994.98	134,974.90
25	BRRC03 > BRSC02	Double-trailer truck	140,145	6	9,772.56	11,276.03
26	BRRC03 > BRSC02	Semitrailer	252,455	17	6,625.54	21,660.42

Table A2. MX Baseline

Row	Origin > Destination	Vehicle	Packages/ Month	Trips	CPR MXN	Freight USD/ Month
5	MXRC03 > MXGT01	Mexican semitrailer	2,725,016	235	20,730.00	263,327.03
6	MXRC03 > MXJC01	Mexican semitrailer	2,698,189	170	27,400.00	251,783.78
7	MXRC03 > MXNL01	Mexican semitrailer	3,279,968	213	36,000.00	414,486.49
8	MXRC03 > MXYU01	Mexican semitrailer	1,185,800	155	66,252.00	555,084.32

APPENDIX B — SPR AND TRIPS BY ROUTE AND VEHICLE

Source [1], Lane Data!H5:M26; Proposed SPR is common to S1 and S2. Values for each row use the stored rounded Current SPR; Avoided Trips are calculated directly using Current Trips and SPR Gain. Fractional values represent planning equivalents.

Table B1. SPR by Vehicle — BR

Row	Origin > Destination	Vehicle	Current SPR	SPR S1/S2	SPR Increase	Future Trips	Avoided/ Month
9	BRRC01 > BRBA01	Double-trailer truck	23,090	30,017.00	6,927.00	52.31	15.69
10	BRRC01 > BRBA01	Semitrailer	13,816	17,960.80	4,144.80	3.08	0.92
11	BRRC01 > BRPE01	Double-trailer truck	22,404	29,125.20	6,721.20	30.77	9.23
12	BRRC01 > BRPE01	Semitrailer	13,083	17,007.90	3,924.90	21.54	6.46
13	BRRC01 > BRSC02	Double-trailer truck	24,332	31,631.60	7,299.60	39.23	11.77
14	BRRC01 > BRSC02	Semitrailer	14,911	19,384.30	4,473.30	13.85	4.15
15	BRRC01 > BRSC02	Extended semitrailer	15,464	20,103.20	4,639.20	20.00	6.00
16	BRRC02 > BRBA01	Double-trailer truck	21,611	28,094.30	6,483.30	20.00	6.00
17	BRRC02 > BRBA01	Semitrailer	12,967	16,857.10	3,890.10	3.08	0.92
18	BRRC02 > BRPE01	Double-trailer truck	20,602	26,782.60	6,180.60	16.92	5.08
19	BRRC02 > BRPE01	Semitrailer	12,890	16,757.00	3,867.00	1.54	0.46
20	BRRC02 > BRSC02	Double-trailer truck	24,166	31,415.80	7,249.80	21.54	6.46
21	BRRC02 > BRSC02	Semitrailer	15,138	19,679.40	4,541.40	1.54	0.46
22	BRRC03 > BRBA01	Double-trailer truck	19,952	25,937.60	5,985.60	3.85	1.15
23	BRRC03 > BRBA01	Semitrailer	14,293	18,580.90	4,287.90	12.31	3.69
24	BRRC03 > BRPE01	Semitrailer	11,182	14,536.60	3,354.60	20.00	6.00
25	BRRC03 > BRSC02	Double-trailer truck	23,358	30,365.40	7,007.40	4.62	1.38
26	BRRC03 > BRSC02	Semitrailer	14,850	19,305.00	4,455.00	13.08	3.92

Table B2. SPR by Vehicle — MX

Row	Origin > Destination	Vehicle	Current SPR	SPR S1/S2	SPR Increase	Future Trips	Avoided/ Month
5	MXRC03 > MXGT01	Mexican semitrailer	11,596	14,379.04	2,783.04	189.52	45.48
6	MXRC03 > MXJC01	Mexican semitrailer	15,872	19,681.28	3,809.28	137.10	32.90
7	MXRC03 > MXNL01	Mexican semitrailer	15,399	19,094.76	3,695.76	171.77	41.23
8	MXRC03 > MXYU01	Mexican semitrailer	7,650	9,486.00	1,836.00	125.00	30.00

APPENDIX C — TRACEABILITY AND VERIFICATION

Proof-of-concept tests: presentation [7] for the series of six POCs; reports [9]–[11] for operating times, quality, RFID, and observations; supplementary summary [2]. Personal communication [4] for the additional S2 test involving 2h of loading and 2h of unloading.

Assumptions in copy [5]: Inputs!B26:B27, gains; B18:B19, exchange rates; B33:B49, costs and operating times; B85:B87, days, productive hours, and stabilized months. Dimensionamento!H4:H7 = 3 shifts and H11:H17 = 2 shifts.

Routes, volumes, and rates: Lane Data!A5:I26. Avoided trips and freight: K5:M26. HC and equipment: N29, O29, P29, and R29. Columns U:W: transport units per trip, proposed trips, and proposed transport units.

S1 Benefit: Lane Data!M29+N29+R29−O29 = RE!B18. S2 Benefit: M29+N29+R29−P29 = RE!C18. Annualization: RE!B19:C19. Capacity: Dimensionamento!U4:AE7 and U11:AE17, with demand, available hours, and utilization by site.

Complete CAPEX: Inputs!B66 = CAPEX!F21 for S1; Inputs!B81 = CAPEX!F40 for S2.

In the revised copy, CAPEX!D7 and D10 include the complete quantities for BRPE01 and MXYU01.

Verifications: aggregation of volumes and trips; reconstruction of freight costs by route; reconciliation of costs per transport unit and monthly and annual benefits; calculation of capacity by site. The revised copy preserves the baseline data from the original file and incorporates the operational definitions provided by the person responsible for the project.