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Leased Trailer Milestone Tracking for Cost Allocation in SAP Transportation Management

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Abstract: ***Leased trailer costs are often invoiced monthly, while utilization occurs across many freight orders and execution states. This paper proposes an event-day allocation model for SAP Transportation Management that links trailer pickup, return, freight order status, agreement validity, and service order creation. The method assigns each chargeable trailer day to used, in use, or unused and applies a conservation rule to prevent duplicate counting across overlapping freight orders. In an April 2026 representative dataset, the model reconciled 90 chargeable trailer days and USD 900 across three trailers, consisting of 35 used days, 7 in-use days, and 48 unused days. Compared with spreadsheet, standard document-based, and attribute-based allocation baselines, the method preserved idle capacity visibility, produced zero duplicate trailer day allocation, and maintained traceability from event to service order. Validation covered 80 scenarios including edge cases and financial reconciliation.***

Keywords: Cost Allocation, Event Day Model, SAP Transportation Management, Service Orders, Trailer Utilization

1. Introduction

Transportation management platforms provide strong support for freight order planning, execution, charge calculation, and settlement. However, leased equipment creates a distinct allocation problem because supplier invoices are often monthly, while actual operational consumption is distributed across several freight orders, customers, locations, and execution statuses.

Conventional practice normally follows one of four techniques. First, spreadsheet allocation reconstructs pickup and return dates manually; this is flexible, but it is difficult to audit and can change when different users interpret missing events differently. Second, standard SAP TM charge calculation supports document-based transportation charges through agreements, calculation sheets, and rate tables. Still, it does not by itself define ownership of each day of a monthly leased trailer across overlapping freight orders. Third, attribute-based allocation, such as weight-, volume-, quantity-, or distance-based distribution, is useful for freight cost distribution but does not preserve idle trailer capacity. Fourth, manual service order creation can post a lease charge, but it does not provide a reproducible rule that links every trailer day to operational evidence.

The contribution of this work is a formal event day model and an SAP TM implementation architecture. The model partitions every chargeable trailer day into exactly one category, used, in use, or unused, and applies a conservation rule before any service order is created. The implementation contribution is the controlled integration of trailer events, freight orders, agreement rates, charge type mapping, and service order creation into a traceable monthly process.

The remainder of this paper is organized as follows. Section 2 reviews related work and positions the contribution relative to recent transportation cost allocation research. Section 3 defines the business problem, research objectives, and novelty boundary. Section 4 presents the proposed methodology, covering the system architecture and process model, the event day allocation model, and the implementation design. Section 5 reports the validation framework, representative results, baseline comparisons, and discussion. Section 6 concludes the paper, and Section 7 outlines the limitations and future scope.

2. Literature Survey

Recent research has continued to advance transportation cost allocation through dynamic collaborative models [10], preference learning for coalition bundle selection [11], optimized transportation cost solving [12], and data-driven logistics cost management [13], yet these approaches divide a cost quantity that is already known rather than resolving a monthly leased resource invoice into event-supported daily observations. The research gap is therefore the absence of a reproducible event day allocation model that connects trailer lifecycle events, freight order status, agreement validity, and settlement quantities while preventing duplicate use of the same trailer day. This gap is operational because it affects dispatch visibility, and it is financial because it affects monthly supplier reconciliation and cost object assignment.

Method families evaluated later in this paper as baselines, namely manual spreadsheet allocation, standard document-based charge processing, and attribute-based allocation, remain active in the current literature. Recent collaborative and game theoretic allocation research continues to refine how a shared cost is divided, for example, the disruption-reason-based dynamic allocation of Guo and colleagues [10] and the preference learning approach of Elting and colleagues [11]. Optimization-based transportation cost solving has advanced through methods such as the one reported by Kalhoro and colleagues [12], and data-driven logistics cost management has been extended to connected environments by Wang and Liu [13]. These recent methods share one assumption: the quantity to be allocated is already known, and they optimize how that quantity is divided among partners, orders, or routes.

The contribution presented here operates one step earlier. A monthly leased trailer invoice must first be resolved into event-supported daily observations, and the idle portion must remain separately visible rather than dissolve into an order-level driver. None of the recent methods above define a per-day partition of a leased resource into used, in use, and unused classes governed by a conservation rule that prevents duplicate day counting before a service order is created. The contribution is therefore complementary to recent allocation research, because it supplies the auditable daily quantity on which those allocation techniques can subsequently operate.

3. Problem Definition

Operational challenges

The problem addressed in this work is the lack of a deterministic link between monthly leased trailer invoices and freight order-level evidence explaining how the leased resource was used. Without integrated trailer milestones, dispatchers cannot consistently determine where a leased trailer is located, how long it has been controlled by the operation, which freight order consumed the lease capacity, or which part of the invoice represents unused capacity.

The cost object is another source of ambiguity. A completed freight order can receive a usage charge, an open freight order may still hold the trailer at a customer location, and an unused leased day may need to be retained as sunk cost or redistributed by policy. If these situations are not separated mathematically, the same trailer day can be counted twice, or an idle day can disappear into a general monthly expense.

Design objectives

The objectives are to define a reproducible trailer day allocation rule, provide end-to-end visibility of trailer movements, associate each trailer with the correct freight order and vendor, calculate chargeable days within the agreement period, and generate billing-relevant service order quantities. The model must also support exception handling, role-based control, reporting, and reconstruction of the event-to-cost trail.

A further objective is to separate standard platform capability from the proposed extension. SAP TM remains the execution, charge, and settlement platform. The proposed method adds event-day partitioning, duplicate prevention, and trailer-specific monthly allocation logic required for leased equipment.

Novelty boundary

The standard platform functions used in this work are freight orders, service orders, charge calculation, agreement-based rates, freight settlement, event reporting, and role-based authorization. These capabilities provide the document and financial foundation of the process.

The newly introduced contribution is the trailer day allocation layer. It converts pickup, return, freight order status, and agreement validity into three disjoint day sets and prevents service order creation unless the conservation rule is satisfied. This boundary clarifies that the research contribution is an allocation model and not a claim to replace standard SAP TM functionality.

4. Methodology / Approach

4.1 System architecture and process model

a) Trailer identification and event capture

Each leased trailer is represented by a unique trailer number, registration number, or pool identifier and is linked to vendor, ownership, and equipment attributes. The identifier is stored on the active vehicle resource item or the trailer item of the freight order [1]. This link is essential because events without a stable trailer identifier cannot be attributed to the correct asset, and a trailer without a freight order reference cannot be allocated to the correct transportation document.

Operational events such as TRAILER PICKUP and TRAILER DROP can be received from a mobile application, terminal interface, electronic data interchange message, application programming interface, or controlled manual correction. Each event should contain the trailer identifier, related freight order, event type, timestamp, time zone, location, source system, and user or operator where applicable. SAP TM execution and tracking functions allow planned and unplanned events to update freight documents [2,3]. The event timestamps are normalized before day allocation so that operations in different time zones do not create inconsistent calendar day counts.

b) Utilization Categories

The monthly model classifies every chargeable agreement day for each trailer into one mutually exclusive category. USED represents a day supported by an executed freight order and a qualifying trailer usage interval. INUSE represents a day after pickup when the freight order remains not started or in execution and no qualifying return or completion event has closed the interval. UNUSED represents an agreement day for which no qualifying used or in use interval exists. A precedence rule assigns a day to USED before INUSE and to INUSE before UNUSED. This ensures that a single calendar day cannot be charged more than once.

Table 1: Utilization categories and charge type derivation

Category	Operational basis	Derived charge type
USED	Executed freight order and qualifying trailer usage interval	ZTRAILER_FIXED
INUSE	Pickup recorded and freight order not started or in execution	ZTRAILER_FIXED
UNUSED	Agreement day without qualifying trailer usage	ZTRAILER_FIX_UN

c) Event to settlement flow

The custom monthly report ZTM_TRAILER_LEASE_REPORT is the orchestration point. It reads the accounting period, agreement, service, vendor, trailer master, freight orders, and persisted milestone data. It validates master data, constructs date intervals, removes duplicate consumption, classifies the remaining days, and displays an ALV worklist with subtotals and freight order navigation. An authorized user can then create service orders that carry the freight order reference, vendor context, charge type, quantity, rate basis, and reporting period.

Table 2: Event to settlement processing sequence

Step	Processing outcome
1. Event capture	Receive pickup, return, status, timestamp, location, and source information.
2. Document linkage	Resolve the trailer identifier and related SAP TM freight order.
3. Day classification	Assign each valid agreement day to USED, INUSE, or UNUSED.
4. Rate determination	Read the date-effective agreement rate and applicable charge-type mapping.
5. Financial document	Create controlled service order lines and retain the allocation trace.
6. Reconciliation	Compare system-calculated quantities and amounts with the supplier invoice.

The service orders can support supplier settlement, general ledger mapping, management reporting, and invoice reconciliation [4-6]. The report does not replace the standard SAP TM documents. Freight orders remain the execution basis, events remain the operational evidence, agreements remain the rate source, and the service order carries the additional trailer service into the downstream financial process.

4.2 Proposed event day allocation model

a) Mathematical allocation rule

For a trailer t and accounting month m, let A(t,m) be the set of chargeable calendar days covered by the applicable agreement. The proposed algorithm creates three disjoint subsets: S_used for executed freight order consumption, S_inuse for open pickup-to-return intervals that are not yet completed, and S_unused for agreement days without qualifying trailer use. The same calendar day cannot appear in more than one subset.

$$A(t,m) = S\_used(t,m) \cup S\_inuse(t,m) \cup S\_unused(t,m) \quad (1)$$

$$D\_total(t,m) = D\_used(t,m) + D\_inuse(t,m) + D\_unused(t,m) \quad (2)$$

$$D\_unused(t,m) = \max\{0, D\_total(t,m) - D\_used(t,m) - D\_inuse(t,m)\} \quad (3)$$

The theoretical basis of the method is a partition and conservation rule. If the three subsets are pairwise disjoint and their union equals the chargeable agreement set, then every leased trailer day is assigned exactly once. This property prevents duplicate day consumption across overlapping freight orders and makes missing or inconsistent events visible because the conservation equation fails before financial posting.

The allocation algorithm follows five deterministic steps. First, events are normalized by location, date, and time zone. Second, pickup, return, and freight order status intervals are converted into candidate date sets. Third, overlap precedence assigns executed dates to USED before INUSE and INUSE before UNUSED. Fourth, agreement validity restricts the final date set. Fifth, service order quantities are created only after configuration, authorization, duplicate, and conservation checks pass.

b) Agreement rate and amount determination

The service agreement maintains the daily rate for the leased trailer service. SAP TM charge calculation uses agreements, calculation sheets, rate tables, and business document attributes to determine transportation charges [4,5]. The custom logic applies the valid daily rate to each classified date. The same rate can be used for active and unused quantities, or a separate unused tariff can be introduced through configuration.

$$C\_active(t,m) = \Sigma\, r(t,d) \text{ for every USED and INUSE date } d \quad (4)$$

$$C\_unused(t,m) = \Sigma\, r(t,d) \text{ for every UNUSED date } d \quad (5)$$

For unused or sunk cost allocation, two approaches were evaluated. Equal distribution spreads the unused amount evenly across executed freight orders, but it does not reflect relative utilization. Proportional distribution [7] allocates the unused amount according to each freight order's share of actual trailer usage. For example, an order that consumes ten days receives twice the allocation of an order that consumes five days. The proportional approach is preferred because it is more transparent and operationally grounded, while the design still allows a regional finance policy to keep unused cost on a central object.

Date-effective summation supports a rate change within the month without forcing a blended monthly rate. Currency rounding is applied at the charge line level, and the report total must equal the sum of all created service order lines. This preserves traceability from the supplier invoice to the daily quantities, agreement versions, and freight order assignments used in the calculation.

c) Configuration and controls

The custom table ZTM_TRAILER_CHG_MAP maps purchasing organization, dispatch center, and utilization category to a charge type. A specific organizational entry takes precedence over a wildcard entry. Missing configuration raises an application error that identifies the unresolved category and prevents posting. Duplicate detection checks the trailer, freight order, agreement, and month before service order creation. Authorization separates report visibility from the ability to create financially relevant documents.

Manual corrections are permitted only for authorized users and should retain the original value, corrected value, user, timestamp, and reason. Additional controls validate mandatory selection fields, agreement status and validity, vendor consistency, trailer master data, event sequence, currency, and zero quantity conditions. These checks reduce the possibility that an incomplete operational record becomes a financial posting.

4.3 Implementation design

a) Trailer identifier on the freight order

The trailer identifier is maintained on the freight order resource item and becomes the common key between execution events, the monthly utilization report, and service

order creation. Figure 1 shows the relevant area of the freight order screen. The production design can use the registration number, trailer or chassis registration number, or a dedicated custom field, provided that the selected key is stable across the event source and the SAP TM document.

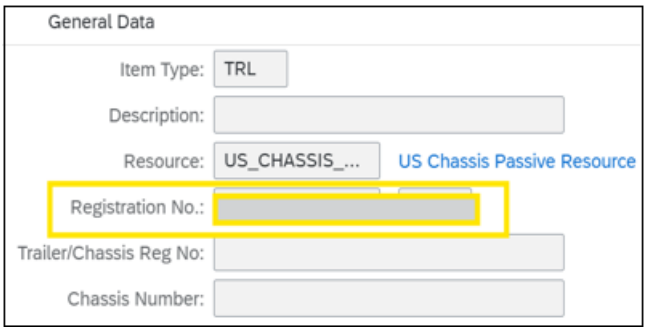

Figure 1: Trailer or chassis identifier maintained on the SAP TM freight order resource item.

b) Report selection and monthly output

The report selection combines the accounting period with agreement, service, vendor, contract, and invoice context. Lookup support resolves operational identifiers without requiring users to know every technical key. The report validates the selections before reading the large freight order and event datasets. This early validation avoids unnecessary processing and provides a clear message when an agreement, vendor, or mandatory field is invalid.

Field Name	*Input*	*Label*
Date Range	2026-04-01 |2026-04-30	FRO In Created/In execution/executed
Services	Leased Trailer	Actual Strategy Indicator from FRO
Vendor ID	165432	Lookup option
Contract ID	123456	Calculation Base

Figure 2: Representative selection parameters and lookup attributes for the monthly leased trailer report

	Unused Days(Sunk Cost)	Inuse Days (In Execution (Trailer Pk Event))	Used Days (Executed Freight Order)	Total Days
Trailer1	***5***	***7***	***18***	**30**
Freight Order 1		7		
Freight Order 2			18	
Trailer2	***13***	***0***	***17***	**30**
Freight Order 3			4	
Freight Order 4			4	
Freight Order 5			9	
Trailer3	***30***	***0***	***0***	**30**

Figure 3: Representative ALV utilization output grouped by trailer and freight order

The ALV output groups records by trailer and freight order and presents unused, in use, used, and total days together with subtotals and grand totals. Freight order entries act as navigation hotspots. Service order actions are enabled only after the mandatory field, agreement validity, configuration, duplicate, and authorization checks have been completed. The report also returns a processing log so that successful and failed documents can be reviewed independently.

c) Service order creation and exception handling

The primary option creates service orders directly from the monthly report. A separate service order is created for each eligible freight order when freight order level allocation is required. Used and in use quantities are combined under ZTRAILER_FIXED, while unused quantities are represented by ZTRAILER_FIX_UN or allocated according to the configured finance rule. A custom action from the freight order user interface can serve as a semi-automated fallback, and standard manual service order creation remains available for exceptional cases.

If a required mapping is missing, a rate is not found, a trailer is not linked to the freight order, or a duplicate service order already exists, the affected record is not posted. The report retains the error reason and allows the user to correct the source information before reprocessing. This item-level behavior prevents one invalid record from hiding the outcome of the remaining valid records.

5. Results and Discussion

5.1 Test coverage

The design is validated through 80 business scenarios organized into eleven categories. The revised validation set expands the earlier acceptance tests by adding late events, corrected timestamps, cross-time-zone event sequences, overlapping freight orders with different organizational ownership, canceled orders, mid-month agreement changes, AP and GL mapping, vendor invoice reconciliation, authorization, override, and end-to-end service order processing.

Table 3: Validation scenario coverage

Validation area	Number
Report input and selection screen	6
Day calculation and usage categorization	14
Charge type mapping and configuration	7
Service order creation	12
Agreement and rate determination	8
Validation and error handling	8
Financial integration and amounts	8
Authorization and security	3
Performance and volume	3
Trailer master data and event linkage	6
Edge and negative conditions	5
Total	80

The six report input scenarios cover valid execution, invalid agreement, invalid vendor, no activity month, agreement outside validity, and missing mandatory fields. The expanded categories add corrected event timestamps, cross-time-zone intervals, late return events, canceled freight orders, mid-month rate changes, cross-organizational trailer sharing, and AP and GL reconciliation checks.

Table 4: Selected validation scenarios and acceptance conditions

Scenario	Condition	Expected result
Valid report execution	Active agreement, valid vendor, and complete selections	Trailer and freight order utilization is displayed with correct totals.
Overlapping freight orders	Two orders use one trailer on the same calendar date	The date is counted once and assigned by the precedence rule.

Corrected timestamp	An event timestamp is corrected after initial posting	The system recalculates the day set, and the audit trail retains the prior value.
Cross time zone event	Pickup and return events occur in different local time zones	Normalized dates prevent artificial extra or missing days.
Missing return event	Pickup exists, but no qualifying return is received	The open interval is classified as INUSE or routed to exception.
Canceled freight order	A freight order is canceled after trailer events exist	The interval is reversed or blocked from financial posting, per policy.
Mid-month agreement change	Daily rate changes during the reporting month	Each date uses the rate effective on that date.
Duplicate creation	A service order already exists for the trailer, order, agreement, and month.	The second creation is blocked, and the existing document is reported.

5.2 Representative monthly calculation

The representative report covers 1 to 30 April 2026. Three leased trailers are each subject to 30 chargeable agreement days. Trailer 1 records 18 used days, 7 in-use days, and 5 unused days. Trailer 2 records 17 used days and 13 unused days. Trailer 3 has no qualifying freight order activity and therefore records 30 unused days. Across the three trailers, the conservation rule is satisfied with 35 used days, 7 in-use days, and 48 unused days, totaling 90 chargeable days.

Table 5: Representative April utilization

Trailer	Used days	In use days	Unused days	Total
Trailer 1	18	7	5	30
Trailer 2	17	0	13	30
Trailer 3	0	0	30	30
Total	35	7	48	90

At a representative daily rate of USD 10, Trailer 1 produces an active charge of USD 250 and an unused charge of USD 50. Trailer 2 produces USD 170 in active cost and USD 130 in unused cost. Trailer 3 produces only an unused charge of USD 300. The three trailers reconcile to USD 900 for the month, consisting of USD 420 for used and in-use capacity and USD 480 for unused capacity.

Table 6: Representative April cost at USD 10 per day

Trailer	Active cost	Unused cost	Total cost
Trailer 1	USD 250	USD 50	USD 300
Trailer 2	USD 170	USD 130	USD 300
Trailer 3	USD 0	USD 300	USD 300
Total	USD 420	USD 480	USD 900

The example demonstrates complete monthly reconciliation while retaining the distinction between freight order consumed capacity and idle lease capacity. It also demonstrates the theoretical partition property: 90 total trailer days equal 35 used days plus 7 in-use days plus 48 unused days, with zero duplicate trailer day assignments.

5.3 Quantitative comparison with baseline methods

To make the comparison reproducible, the same April data set, reporting period, trailer pool, daily rate, and reconciliation target are applied to four allocation methods. The baselines represent common spreadsheet practice, standard SAP TM document-based charge processing, and current enterprise TMS [8-9] attribute-based allocation such as weight-, volume-, quantity-, or distance-based distribution.

Manual spreadsheet allocation can be made to match USD 900 for the April data set, but the result depends on user-maintained formulas and interpretation of missing events. Idle capacity visibility and duplicate day control are not enforced by the method itself.

Standard document-based charge processing supports freight and service order settlement. Still, the same April data set does not isolate the 48 unused trailer days unless an additional event day rule is introduced. Attribute-based allocation can distribute cost by weight, volume, quantity, or distance, but it blends the USD 480 idle lease capacity into order-level allocation.

The proposed event day model reconciles the same USD 900, separates USD 420 active utilization cost from USD 480 unused capacity, and produces zero duplicate trailer day assignments. This comparison shows that the benefit is not only arithmetic reconciliation; it is the auditable classification of every trailer day before service order creation.

5.4 Performance, security, and reconciliation acceptance

The performance suite includes approximately ten thousand freight order rows and a batch that creates more than fifty service orders. These values are acceptance test targets rather than universal performance guarantees. Runtime depends on database volume, indexing, event persistence, agreement complexity, and system sizing. The revised validation set also checks idempotent rerun behavior so that the same month cannot create duplicate service order lines.

Security scenarios confirm that a user may be permitted to execute the report while service order creation remains hidden or blocked. Financial scenarios verify charge type-to-GL mapping, downstream report visibility, currency rounding, AP reconciliation, and the ability to compare supplier invoice lines with system-calculated usage. Production logs are not included because they can contain confidential operational data; therefore, the manuscript uses anonymized representative data with explicit inputs, outputs, and baseline assumptions.

6. Discussion

The main architectural benefit is the separation of operational evidence, allocation logic, configuration, and financial output. Trailer events establish when the resource is physically controlled or used. Freight order status establishes whether the day is executed or still in progress. Agreement data establishes the chargeable period and daily rate. The mapping table establishes the financial classification. Because these concerns are separated, the model can be reused for different vendors, dispatch centers, or trailer pools without rewriting the calculation engine.

The unique day union is particularly important. A simple sum of freight order durations can overstate utilization when orders overlap or when one order finishes and another begins on the same date. Allocating dates rather than raw durations enforces a monthly conservation rule in which every chargeable agreement day belongs to exactly one category. A discrepancy is therefore visible before it becomes a service order or a supplier settlement difference.

The model also creates a clearer operational and financial conversation. Dispatchers can see the physical sequence, procurement can verify agreement quantities, finance can reconcile supplier invoices, and audit users can trace each posted quantity back to the trailer day that caused it. This is the main scientific contribution: the method converts a monthly resource invoice into a formally partitioned set of event-supported daily observations.

Although the design is described for leased trailers, the same architecture can be extended to other monthly leased resources whose utilization is represented by operational milestones. Examples include chassis, swap bodies, containers, and specialized equipment. The category names and charge types may change, but the core concepts of identifier linkage, date classification, agreement validity, and controlled financial document creation remain applicable.

7. Conclusion

This paper presented an event day allocation model for leased trailer cost settlement in SAP Transportation Management. The proposed method improves on manual, document-based, and attribute-based allocation by assigning every chargeable trailer day to exactly one utilization class: used, in use, or unused. In the representative April 2026 data set, the method reconciled 90 trailer days and USD 900 of monthly cost across three trailers while separately identifying USD 420 of active utilization cost and USD 480 of unused lease capacity.

The theoretical contribution is the partition and conservation rule, which prevents duplicate day counting and exposes missing or inconsistent event data before service order creation. The validation was expanded to 80 scenarios covering calculation accuracy, agreement validity, late events, corrected timestamps, canceled orders, authorization, AP, GL, vendor reconciliation, and exception handling. By preserving the relationship between event, trailer, freight order, agreement, charge line, and supplier invoice, the model provides a reproducible basis for monthly reconciliation rather than only a system implementation.

8. Future Scope

The design depends on timely and consistent trailer identifiers and event timestamps. A missing pickup or return event can misclassify an active day as unused, while a duplicate or late event can reopen a closed interval. Production deployment therefore requires event monitoring, deduplication, time zone rules, controlled corrections, and an exception queue. The business must also define responsibility for unused cost, canceled orders, agreement changes, and days that cross organizational boundaries.

The representative validation demonstrates the correctness of the proposed rules, but it is not a statistical study of production utilization or financial savings. Actual operational benefits depend on data quality, event timeliness, organizational policy for unused cost, and the degree of automation in downstream invoice matching. Future work should evaluate larger anonymized production data sets and compare error reduction before and after implementation.

Future enhancements can include automatic invoice line matching, anomaly detection for implausible event sequences, mobile geofencing, predictive alerts before free time or agreement thresholds are exceeded, and analytics comparing utilization across vendors and locations. A configurable distribution rule could allocate unused lease cost to a central cost object, active freight orders, or a separate management reporting bucket. Additional controls could also score event quality and prevent automatic settlement when the evidence falls below a defined confidence threshold.

Conflicts of interest
The author declares no conflict of interest.

Author Contributions
Conceptualization, methodology, system design, validation framework, formal analysis, investigation, visualization, writing original draft preparation, and writing review and editing, Ajay Bhaktharahalli Nagesh Hemambika. The author reviewed and approved the final manuscript and accepts responsibility for its accuracy and integrity.

Use of artificial intelligence tools
Language editing and document formatting tools were used to improve readability and layout. The author reviewed and validated the technical content, calculations, figures, tables, and conclusions.

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