JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

The Freight Unit As The Atomic Planning Currency: Building Logic, Split Determinants, And Package Hierarchy In Enterprise Transportation Systems

[1]Ajay Bhaktharahalli Nagesh Hemambika, [2]Rajashiva Ramalingam

[1]Sr. Software Engineer, SAP Transportation Management, A. P. Moller Maersk, Charlotte, NC, USA
[2]Manager, SAP Transportation Management and Warehouse Applications, ACCO Brands Corp, Lake Zurich, IL, USA

Abstract: Transportation planning in enterprise logistics systems operates on a construct called the freight unit: the atomic planning currency that sits between the business document layer (orders, deliveries) and the execution layer (freight orders, carrier assignments). This paper examines the freight unit in depth, covering its role in the transportation document hierarchy, the determinants that cause a single order item to be split into multiple freight units, the structure and configuration of the freight unit building rule, the distinction between embedded and side-by-side deployment architectures and their effect on freight unit creation, and the package building process that bridges the freight unit to physical packaging reality. We draw on logistics systems research and enterprise implementation experience to argue that misconfigurations in freight unit-building rules are among the most consequential yet least visible sources of planning-quality problems in production transportation management deployments. The paper concludes with practical guidance on rule calibration and on selecting a package-building strategy.

***Index Terms*:** embedded TM, enterprise transportation management, freight unit, freight unit building rule, logistics planning, package building, side-by-side deployment, split quantity, transportation requirement.

I. INTRODUCTION

Every logistics planner who has worked with a modern transportation management system has encountered moments where the system seems to plan against them. A shipment that logically belongs together gets split across two trucks. A consolidation that should be straightforward refuses to form. Carrier assignments look wrong for reasons that are not immediately obvious. In a large share of these cases, the root cause is neither the optimizer nor the planning profile. It is the freight unit.

In enterprise transportation planning, the freight unit is the fundamental unit of currency. It is not a physical object. It is a data construct that represents a quantity of goods to be transported together, defined by shared origin, destination, timing constraints, and compatibility characteristics. The optimizer does not see orders or deliveries. It sees freight units. The carrier does not receive an order. It receives a freight order built from freight units. Getting the freight unit building right is, therefore, foundational to every subsequent planning outcome.

Despite this centrality, freight unit building receives relatively little attention in enterprise logistics literature. Most published work on transportation optimization focuses on algorithms and cost function design. The data structures that feed those algorithms are treated as given. This paper argues that they are not given and that the rules governing freight unit construction deserve the same rigorous attention as the planning algorithms that consume them.

We organize the paper as follows. Section II reviews the freight unit's position in the transportation document hierarchy. Section III analyzes the three determinants of freight unit splits. Section IV examines the freight unit building rule and its configuration parameters. Section V compares embedded and side-by-side deployment architectures. Section VI covers package building. Section VII discusses implementation implications, and Section VIII concludes.

II. THE FREIGHT UNIT IN THE TRANSPORTATION DOCUMENT HIERARCHY

A. From Business Event to Planning Object

Transportation planning in enterprise logistics begins not with vehicles or routes but with a business event: a customer places an order, a purchase order triggers an inbound delivery, or a forwarding order is received from a shipper. These events live in the business document layer, expressed as sales orders, purchase orders, deliveries, forwarding orders, or their equivalents. They carry the commercial logic of the transaction but not the planning logic of transportation.

Between the business document layer and the execution layer lies the planning layer, and the freight unit is its basic building block. A freight unit aggregates one or more items from one or more predecessor documents into a single planning object with a defined origin, destination, pickup window, delivery window, weight, volume, and set of compatibility attributes. The transportation optimizer sees this object as an indivisible unit: it must be assigned to a vehicle or carrier as a whole, routed as a whole, and tracked as a whole through the execution process [3]. That intermediate step has a name: the transportation requirement.

When a sales order or delivery is flagged as transportation-relevant, the system creates a transportation requirement that captures the logistics-relevant attributes. When a sales order or delivery is flagged as transportation-relevant, the system creates a transportation requirement that captures the logistics-relevant attributes. Freight unit building then reads these requirements, applies the freight unit building rule, and generates one or more freight units [16].

FREIGHT UNIT POSITION IN THE TRANSPORTATION DOCUMENT CHAIN				
Sales Order / Purchase Order	Delivery / OTR / DTR	**FREIGHT UNIT (Planning Unit)**	Freight Order	Transport Execution
Business Trigger	Transportation Requirement	Atomic Planning Unit	Carrier Assignment	Physical Movement
FUBR determines how predecessor documents are grouped into freight units				

Fig. 1 Freight unit position in the transportation document chain: from business trigger through transportation requirement and freight unit building to freight order and physical execution.

B. The Freight Unit as the Optimizer's View of Demand

Understanding why the freight unit is the correct level of abstraction for planning requires appreciating which information the optimizer needs and which it does not. The optimizer needs to know what goods must move, from where to where, under what time constraints, with what physical dimensions, and subject to what compatibility restrictions. It does not need to know which sales order line generated the demand or what the commercial margin is.

The freight unit strips the predecessor document down to exactly what the optimizer needs and nothing more. This abstraction serves a second purpose: it decouples planning from the transactional document structure. A single freight order can consolidate freight units that originated from different sales orders, different customers, or even different business units, as long as compatibility rules permit. Without the freight unit abstraction, this consolidation would require the optimizer to reason about commercial document structures [12].

III. WHAT CAUSES A SINGLE ORDER ITEM TO GENERATE MULTIPLE FREIGHT UNITS

A. The Three Split Determinants

One of the first things that surprises practitioners new to enterprise transportation planning is that a single delivery line item can generate multiple freight units. A customer orders 50 pallets. The system creates three freight units from that single line. Why? The freight unit building logic applies three categories of split criteria simultaneously, and any one of them can cause the item to be divided [4].

The first category consists of hard constraints on the source and destination. If items in the same delivery are bound for different ship-from locations or have different pickup date constraints, the system splits them into separate freight units. Location and date constraints are inviolable: goods that cannot physically depart from the same point at the same time cannot share a freight unit regardless of any other attribute.

The second category is incompatibilities. Items with incompatible attributes cannot share a freight unit, even if their location and date constraints align perfectly. Hazardous material classes with segregation requirements, temperature-sensitive goods that require different compartment settings, and commercially incompatible products all trigger incompatibility-based splits. The incompatibility framework is configured per freight unit type and can capture both regulatory requirements and business policy constraints.

The third category is split quantities defined in the freight unit building rule. Even when location, date, and compatibility constraints are all satisfied, a single item may be too large to fit in a single freight unit. If the order quantity exceeds the maximum defined in the building rule, the system generates multiple freight units, each carrying a portion of the total quantity.

FREIGHT UNIT SPLIT REASONS			
	Order / Delivery Item		
	Hard Constraints (Location, Date, Route)	Incompatibilities (Hazmat, Temperature, Commercial)	Split Quantities (FU Building Rule: Max Weight/Volume)
	Freight Unit 1	**Freight Unit 2**	**Freight Unit 3**
The system evaluates all three split criteria simultaneously.			

Fig. 2 Freight Unit Split Reasons: three independent causes that can each trigger the creation of multiple freight units from a single order or delivery item.

B. Why Split Logic Matters for Planning Quality

The practical consequence of split logic is that the freight unit structure the optimizer receives does not match the order structure the business created. If the split rules are configured conservatively, few splits occur, and freight units are large. The optimizer works with a smaller number of larger objects. If split rules are configured aggressively, many splits occur, and freight units are small. The optimizer has more flexibility to consolidate but must manage a much larger number of objects.

The right calibration depends on the actual capacity of the vehicles used, the typical order quantities in the business, and the degree of consolidation that is operationally desirable. The critical quantity and split quantity parameters in the freight unit building rule are, in effect, a policy statement about the granularity at which the business wants to plan transportation [13].

IV. THE FREIGHT UNIT BUILDING RULE

A. Structure and Core Parameters

Governing the translation from transportation requirements into freight units is a configuration object called the freight unit building rule. It is assigned to a freight unit type, which is, in turn, determined by the predecessor document using a condition technique. Every freight unit created by the system includes a reference to its freight unit type, which in turn includes a reference to its building rule.

The strategy parameter is the first and most fundamental setting. It determines the algorithm used to group items from predecessor documents into freight units. The standard delivered strategy, FUB_AUTO, groups all items from the same predecessor document that share compatible attributes into a single freight unit, subject to the split quantity ceiling. Custom strategies implemented through the process controller framework can override this logic entirely, allowing businesses to implement proprietary grouping rules suited to their operations.

The critical quantity determines the dimension along which the split-quantity ceiling applies. For most shippers, this is weight or volume. The critical quantity setting determines which physical dimension is the binding constraint on freight unit size from the building rule's perspective. If both weight and volume need to be constrained simultaneously, additional dimensional limits can be registered against the building rule, and the system enforces all of them as independent capacity ceilings during planning.

FREIGHT UNIT BUILDING RULE: KEY CONFIGURATION PARAMETERS	
Strategy	Group items by delivery, order, or custom process controller strategy (FUB_AUTO is standard).
Critical Quantity	Primary dimension for a split ceiling: typically, weight or volume.
Item Split Allowed	If enabled, a single line item may be split across multiple freight units.
Split Quantity	Maximum capacity per freight unit. The system creates multiples as needed.
Planning Quantities	Additional dimensions (e.g., volume) copied to FU for capacity checks.
Document Type Determination	Controls which freight unit type is assigned based on predecessor doc type.
Equipment Type	Sizes FU to match physical container; required for containerized shipping.

Fig. 3 Freight Unit Building Rule configuration parameters: each parameter controls a specific aspect of how order items are grouped, sized, and typed during freight unit creation.

B. Item Split and Rounding Logic

The item split allowed flag is one of the most consequential settings in the building rule and one of the most frequently misconfigured. When this flag is enabled, the system is permitted to split a single order line item across multiple freight units. When it is disabled, the item must be kept together even if it exceeds the split quantity. The operational interpretation is straightforward: some goods can be physically divided, while some cannot.

When item split is allowed, the system calculates freight unit quantities as multiples of the rounding quantity up to the split quantity ceiling. Consider a rounding quantity of 250 kg against a split-quantity ceiling of 1,500 kg. The system will generate freight units of 250, 500, 750, 1,000, 1,250, or 1,500 kg depending on the total order quantity. This rounding behavior ensures that freight unit sizes align with practical loading unit boundaries rather than creating awkward partial quantities.

The equipment type parameter links the freight unit to a physical container specification. When an equipment type is assigned in the building rule, the system sizes the freight unit to match the equipment's internal dimensions. It ensures that all goods assigned to that freight unit are packed into the specified equipment during warehouse processing. This parameter is particularly important for containerized ocean shipping [7].

Table 1. Freight Unit Building Rule Parameters and Their Operational Impact

Parameter	Setting Choices	Operational Impact
Strategy	FUB_AUTO or custom process controller	Determines grouping algorithm; custom strategies enable proprietary consolidation logic
Critical Quantity	Weight, Volume, Pieces, or custom UoM	Sets the primary dimension for split quantity enforcement
Item Split Allowed	Yes / No	Controls whether a single line can be split across multiple freight units

Split Quantity	Numeric value in critical quantity UoM	Maximum size of one freight unit; system creates multiples as needed
Rounding Quantity	Numeric; must divide into a split quantity	Ensures freight unit sizes align with practical loading unit boundaries
Equipment Type	Reference to the equipment master record	Size the freight unit to match the physical container, required for containerized shipping
Planning Quantities	Additional dimensional constraints	All defined quantities copied to FU and used in capacity checks

V. EMBEDDED VERSUS SIDE-BY-SIDE DEPLOYMENT: IMPACT ON FREIGHT UNIT CREATION

A. The Architecture Question

The deployment architecture of the transportation management system determines how freight unit creation is triggered, which predecessor documents are available, and how quickly freight units appear after a business event. Two architectures are relevant: embedded deployment, where transportation management runs natively within the same S/4HANA system instance as the business document layer, and side-by-side deployment, where a separate transportation system is connected to the ERP via an integration layer.

In embedded deployment, the freight unit building process is triggered synchronously when a transportation-relevant order or delivery is saved. The freight unit building rule runs in the same database transaction as the predecessor document creation: no interface, no middleware, no delay. If a planner creates a delivery at 9:15 a.m., freight units are available for planning at 9:15 a.m. [8].

In a side-by-side deployment, the ERP creates an order-based transportation requirement (OTR) or a delivery-based transportation requirement (DTR). It transmits it to the separate TM system via an integration platform. The elapsed time between the business event in the ERP and the availability of the freight unit in TM planning depends on the integration configuration.

EMBEDDED VS. SIDE-BY-SIDE DEPLOYMENT		
	Embedded TM (S/4HANA)	**Side-by-Side TM**
Trigger	Sales Order / Delivery in S/4HANA	OTR / DTR via integration middleware
Interface	None. Shared database. Instant.	PI/CPI middleware is required and adds latency.
Predecessor Doc	Sales Order or Delivery (native S/4)	Order-based TR (OTR) or Delivery-based TR (DTR)
FUBR Execution	Same system instance	Separate the TM system after document transfer
Data Consistency	Real-time, no sync needed	Periodic sync; risk of data mismatch
Typical Use Case	New S/4HANA implementations	ECC or legacy ERP is still in use

Fig. 4 Embedded vs. Side-by-Side Deployment: comparison of freight unit creation trigger, interface requirements, predecessor document types, and data consistency characteristics.

B. Practical Implications of Deployment Choice

The architecture choice has consequences beyond latency. In embedded deployment, the freight unit building rule has access to the full richness of the S/4HANA data model, including real-time inventory availability, customer master data, material master data, and any custom fields defined in the business document layer. In side-by-side deployment, only the data explicitly included in the OTR or DTR transmission is available to the building rule.

This data availability constraint is a frequent source of implementation issues in side-by-side deployments. A business may have a well-designed building rule that distinguishes freight unit types based on a hazardous material indicator maintained in the material master. In embedded deployment, this works without any special configuration. In side-by-side deployment, the hazardous material indicator must be explicitly mapped into the OTR or DTR transmission, or the building rule will not see it [8].

VI. PACKAGE BUILDING: BRIDGING FREIGHT UNITS TO PHYSICAL REALITY

A. The Distinction Between Freight Units and Packages

A freight unit represents a planning-level abstraction of goods to be transported. It carries weight, volume, and compatibility attributes that the optimizer uses for planning decisions. It does not, by itself, represent the physical packaging in which those goods will actually travel. The package-building process closes this gap by creating package units that represent the physical containers, pallets, cartons, and inner packs in which the freight unit's goods are packaged for transport.

The package-building process uses product package-type assignments to determine the appropriate packaging hierarchy for each material. A product package type specifies how a material is packaged at each level: how many units fit in an inner pack, how many inner packs fit in a carton, how many cartons stack on a pallet, and what the dimensions and weight of each level are [13].

The distinction between freight unit and package unit matters for two reasons. First, warehouse operations require package-level instructions for picking, packing, and staging freight. Second, load planning, which determines the physical arrangement of goods

in a vehicle or container, operates on package units rather than freight units. Without accurate package building, load-planning calculations will be based on incorrect dimensions.

B. Early, Mixed, and Late Package Building

The system supports three package-building strategies that differ in when packaging is determined during the planning process. The choice between them reflects the business's ability to determine packaging information at each stage of the process.

Early package building occurs before transportation planning begins. The system creates package units from delivery items as soon as the delivery reaches a defined processing stage. Early packaging is appropriate when the packaging configuration is fully determined before planning, for example, when goods are pre-palletized to a fixed standard. The advantage of early packaging is that the optimizer works with accurate dimensional data from the start.

Late package building occurs after the transportation plan and freight order are confirmed. Packaging is determined at the point of physical execution, typically during warehouse picking or at the time of goods issue. Late packaging is appropriate when the final packaging configuration depends on the transport mode or carrier selected during planning, or when order quantities are subject to last-minute adjustment.

Mixed package building occurs during freight order creation, after planning but before execution confirmation. It represents a practical compromise for many real-world scenarios: planning uses freight unit dimensions, and packaging is confirmed once the carrier and route are determined, but before physical handling begins. The package unit multi-assignment capability, available in all three strategies, allows a single freight unit to be associated with packages from multiple origins [16].

PACKAGE BUILDING OPTIONS		
EARLY Package Building	**MIXED Package Building**	**LATE Package Building**
Before planning. Packages are created immediately from delivery items.	During freight order creation. System packages at the FO building point.	After optimization. Packaging performed during execution/goods issue.
Best for: Fixed palletizing standards	Best for: Flexible consolidated shipments	Best for: Dynamic loads; unknown quantities at planning time
Package units track physical packaging hierarchy (inner pack, carton, pallet). Multi-assignment enables consolidation from different origins.		

Fig. 5 Package Building Options: Early, Mixed, and Late packaging strategies and their appropriate use cases in the transportation planning process.

VII. IMPLEMENTATION IMPLICATIONS

A. Building Rule Design as a Planning Quality Driver

Too often treated as a background configuration task, the freight unit building rule deserves to be a first-class design artifact in transportation management implementations. In practice, it is often configured quickly during the technical setup phase, based on simple assumptions about typical order sizes, and never revisited. The consequences of this neglect accumulate quietly over time. As order profiles change, as new product lines are introduced, as carrier capacity constraints evolve, the building rule configured at go-live becomes progressively less representative of actual business conditions.

The most common building rule misconfiguration is a split quantity set too high. When freight units are too large, the optimizer cannot fill vehicles to their actual capacity without awkward partial assignments. Consolidation across different orders becomes difficult because each freight unit already approaches vehicle capacity on its own. The planning output looks reasonable on paper, but consistently underperforms in vehicle utilization. The root cause is not visible in the freight order view; it can only be diagnosed by examining the freight unit data [12].

B. Package Building Strategy Selection

The package-building strategy should be selected based on the business's actual ability to determine packaging information at each stage of the process, rather than on a default assumption. Early packaging is often configured by default because it provides the most accurate planning data, but it is only appropriate when packaging is genuinely deterministic at order time.

A practical approach to strategy selection is to trace the information flow backward from physical packaging reality. Ask when the packaging configuration is actually known with confidence. Is it at order creation? At delivery creation? At freight order confirmation? At the goods issue? The answer determines which packaging strategy is appropriate. Late packaging is frequently underused because it is perceived as sacrificing planning accuracy. Still, for businesses with highly variable final quantities or mode-dependent packaging, it is the honest representation of what the business actually knows at planning time [13].

VIII. CONCLUSION

Planning quality in enterprise transportation management begins with the freight unit, and the freight unit is not a technical detail. It is the fundamental unit of value in transportation planning, and the rules governing its construction determine the quality of every downstream planning output. This paper has traced the freight unit from its origins in the transportation document hierarchy through the three split determinants, the configuration parameters of the building rule, the architectural implications of embedded versus side-by-side deployment, and the package-building process that bridges planning abstraction and physical reality.

Several practical conclusions follow. Freight unit building rule configuration should be treated as a design deliverable that requires the same analysis and validation as planning profile configuration. Split quantities should be calibrated against actual vehicle capacities and order profiles rather than estimated. The item split allowed setting should reflect the goods' genuine physical characteristics, not convenience. The package-building strategy should be selected based on when packaging information is genuinely available within the business process.

The visibility problem that makes freight unit misconfiguration so persistent is that its effects manifest in planning and execution outcomes rather than in the freight unit data itself. Poor plan quality, low vehicle utilization, and execution discrepancies are the symptoms. The building rule is the cause. Developing the diagnostic capability to trace planning problems back to their building rule origins is an investment that consistently delivers returns in transportation management deployments [12].

IX. ACKNOWLEDGMENT

The authors acknowledge the contributions of enterprise logistics implementation professionals whose project experience informed the practitioner perspective in this paper.

REFERENCES

[1] M. Gendreau and J.-Y. Potvin, "Metaheuristics in Combinatorial Optimization," Annals of Operations Research, vol. 140, no. 1, pp. 189-213, 2005.

[2] C. Verderame, J. Elia, J. Li, and C. Floudas, "Planning and Scheduling under Uncertainty: A Review Across Multiple Sectors," Industrial and Engineering Chemistry Research, vol. 49, no. 9, pp. 3993-4017, 2010.

[3] H. Stadtler, C. Kilger, and H. Meyr, Eds., Supply Chain Management and Advanced Planning, 5th ed., Springer, Berlin, pp. 1-502, 2015.

[4] P. Toth and D. Vigo, Eds., Vehicle Routing: Problems, Methods, and Applications, 2nd ed., SIAM, Philadelphia, pp. 1-450, 2014.

[5] M. Savelsbergh and J.-H. Song, "Inventory-Based Versus Transportation-Based Cross-Docking in a Direct Compound Retail Network," European Journal of Operational Research, vol. 203, no. 2, pp. 371-381, 2010.

[6] G. Desaulniers, J. Desrosiers, and M. Solomon, Eds., Column Generation, Springer, New York, pp. 1-358, 2005.

[7] K. Laudon and J. Laudon, Management Information Systems: Managing the Digital Firm, 16th ed., Pearson, New York, pp. 1-624, 2020.

[8] T. Davenport, Mission Critical: Realizing the Promise of Enterprise Systems, Harvard Business School Press, Boston, pp. 1-338, 2000.

[9] G. Perboli, R. Tadei, and D. Vigo, "The Two-Echelon Capacitated Vehicle Routing Problem: Models and Math-Based Heuristics," Transportation Science, vol. 45, no. 3, pp. 364-380, 2011.

[10] J. Drexl, "Synchronization in Vehicle Routing: A Survey of VRPs with Multiple Synchronization Constraints," Transportation Science, vol. 46, no. 3, pp. 297-316, 2012.

[11] C. Barnhart and G. Laporte, Eds., Handbooks in Operations Research and Management Science: Transportation, vol. 14, Elsevier, Amsterdam, pp. 1-656, 2007.

[12] R. Ballou, Business Logistics / Supply Chain Management, 5th ed., Pearson, New York, pp. 1-816, 2004.

[13] J. Mangan, C. Lalwani, and A. Calatayud, Global Logistics and Supply Chain Management, 4th ed., Wiley, Hoboken, pp. 1-408, 2020.

[14] D. Pisinger and S. Ropke, "A General Heuristic for Vehicle Routing Problems," Computers and Operations Research, vol. 34, no. 8, pp. 2403-2435, 2007.

[15] T. Vidal, T. Crainic, M. Gendreau, and C. Prins, "A Hybrid Genetic Algorithm with Adaptive Diversity Management," Computers and Operations Research, vol. 40, no. 1, pp. 475-489, 2013.

[16] S. Chopra and P. Meindl, Supply Chain Management: Strategy, Planning, and Operation, 7th ed., Pearson, New York, pp. 1-528, 2021.

[17] G. Laporte, "Fifty Years of Vehicle Routing," Transportation Science, vol. 43, no. 4, pp. 408-416, 2009.

[18] O. Braysy and M. Gendreau, "Vehicle Routing Problem with Time Windows, Part I," Transportation Science, vol. 39, no. 1, pp. 104-118, 2005.

[19] M. Gronalt and P. Hirsch, "Log-Truck Scheduling with a Tabu Search Strategy," in Metaheuristics, K. Doerner et al., Eds., Springer, New York, pp. 65-88, 2007.

[20] United Nations, European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), UNECE, Geneva, 2023. [Online]. Available: https://unece.org/transport/dangerous-goods/adr-2023