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

Beyond the Basics: Insights into SAP Transportation Management Optimization Algorithms

Sudhir Makkar[1]
Accenture LLP, Washington DC
ORCID: 0009-0007-9688-2579

Andy Desai[2]
Capgemini, Houston TX
ORCID: 0009-0000-7983-0557

***Abstract -** This article delves into the optimization algorithms used within SAP Transportation Management (TM), which play a pivotal role in streamlining transportation logistics for enhanced efficiency, route optimization, and cost reduction. This paper articulates the functionalities of different classes of optimization algorithms, including route and load optimization, carrier selection, and real-time dynamic scheduling, highlighting their strategic implications in real-world scenarios. The paper also explores integrating these algorithms with SAP TM's comprehensive features like freight planning, order management, and warehouse management to foster cost-effective cohesive supply chain solutions. The findings from this review not only demonstrate the robust capabilities of SAP TM's optimization algorithms in improving logistical outcomes but also illustrate their transformative effects on overall supply chain performance, thereby supporting informed decision-making and operational agility in complex logistical networks. This article aims to give stakeholders a deeper understanding of how advanced optimization techniques can be effectively applied within SAP TM to achieve superior logistical efficiency and strategic advantage in the marketplace.*

***Index Terms -** Supply chain management, SAP TM, Digital transformation, Route Optimization, Load Planning, Transportation.*

1. Introduction

The significance of optimization in the field of transportation management cannot be overstated. With the escalating demands and complexities of global supply chains, transportation, and supply chain planners are compelled to seek solutions that reduce transportation costs and enhance the efficiency and reliability of their logistics operations. Optimization algorithms within SAP TM address this gap by offering sophisticated tools for route planning, freight consolidation, carrier selection, and dynamic scheduling, among others. These algorithms transform raw data into actionable insights, allowing companies to make strategic decisions that align with their operational objectives and market demands. SAP Transportation Management (TM) emerges as a befitting solution with new and innovative features (Leader Quadrant of Gartner and Forrester study) [1] designed to streamline these processes by integrating and improving transportation planning, execution, freight billing, and analytics. Its optimization algorithms are central to the functionality of SAP TM, which leverages advanced mathematical models to solve logistical problems creatively and effectively.

Through a thorough examination of their theoretical foundations and real-world implementations, this article aims to clarify the influence of various optimization algorithms on transportation logistics by reviewing their integration and deployment inside SAP TM. The study will evaluate the optimizer rules and algorithm's effect on key performance measures like cost savings, route planning, lead time reductions, and customer satisfaction by examining multiple use cases across different sectors. The paper will also address possible developments in transportation management optimization and future research directions, including the incorporation of cutting-edge technology like artificial intelligence and predictive analytics. The paper will specifically address the following key questions as a guiding force of this study:

1) What are the most effective optimization algorithms for different types of transportation challenges in SAP TM?
2) How can SAP TM's optimization capabilities be enhanced using emerging technologies like AI and predictive analytics?
3) What are the impacts of optimization algorithms on key performance metrics in various industries?
4) How do different planning and selection settings influence the performance of optimization algorithms in SAP TM?
5) Integration of real-time data analytics with SAP TM Optimization algorithms.

2. Literature Review

Freight costs in transportation management are a critical value lever in the supply chain as they add substantially to the overall cost (40-50% of total logistics costs). Optimization algorithms play a significant role in reducing transportation logistics considerably and have the potential to be the game changer. Given the direct relationship between transportation planning and costs, transportation management optimization has been the center of academic literature and industry research attention for decades. A wide range of optimization techniques and algorithms have been proposed to address the various issues in the design and implementation of transport projects. Ritzmann et al. (2016) and Chopra and Meindl (2020) categorize optimization algorithms into heuristic, metaheuristic, and machine learning-based methods. Heuristic algorithms, such as the Nearest Neighbor and Clarke-Wright Savings algorithms, offer quick solutions but may not always be optimal. Metaheuristic approaches, including Genetic Algorithms and Ant Colony Optimization, provide more refined solutions at the cost of computational complexity.

According to the studies of Ritzmann et al. (2016) and Chopra and Meindl (2020) [2][3], advances in optimization methods can be integrated with TMS to provide cost reduction and improve service quality. A pioneering tool for transportation management optimization is the SAP TM Optimizer Algorithm developed by SAP SE: it performs load optimization, and cargo consolidation and reduces transportation costs using machine learning, heuristic algorithms, and mathematical modeling. Jula and Schiefer (2018) [4] show the benefits of using SAP TM with enterprise resource planning (ERP) systems, enabling seamless coordination between transportation planning and other business processes across the enterprise.

3. Methodology

The SAP TM optimization algorithm employs a combination of mathematical modeling and heuristic techniques to solve complex transportation problems. Some of the aspects of its methodology include:

1) **Modeling Constraints**: The algorithm considers various constraints such as vehicle capacity, driver availability, delivery ti me windows, and miscellaneous transportation regulations from the Department of Transportation (DOT), and Environmental Protection Agency (EPA).

2) **Cost Calculation and Optimization**: Key variables, including distance, fuel consumption, tolls, carrier rates, and others, are considered when calculating transportation costs. There are penalties for both late pickup and drop-off.

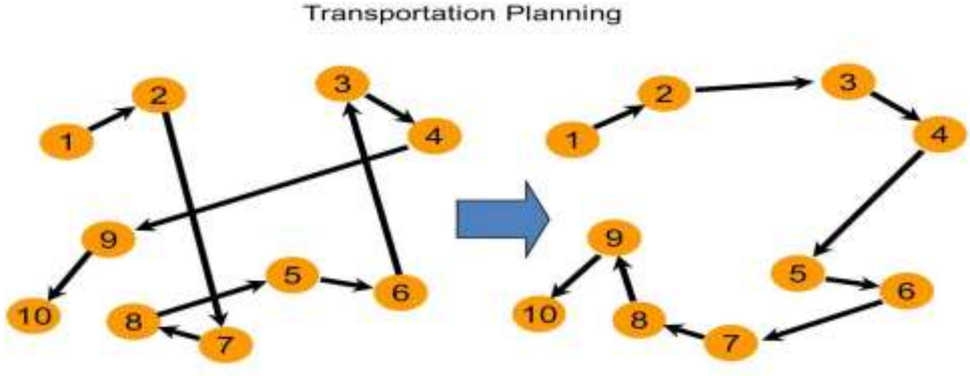
3) **Heuristic Search Techniques**: Due to the complexity of real-world transportation problems (mode of transportation, number of lanes, type of goods, etc.), the algorithm often employs heuristic search techniques to find near-optimal solutions efficiently.

4) **Multi-Modal Optimization**: SAP TM offers the capability to optimize transportation across various modes such as road, rail, air, and ocean freight, providing adaptable and economical solutions. Companies often utilize multi-modal routes to enhance both overall delivery times and optimize transportation expenses.

4. Overview of Optimizer

4.1. Purpose

The goal of the optimizer is to assign tasks to vehicles and determine the route and sequence of tasks per vehicle so that all constraints are met, and total costs are minimized. The optimizer achieves this goal by evolutionary local search, a population-based meta-heuristic that borrows selection principles from evolutionary algorithms and relies heavily on local optimization [7].



The optimizer creates a mathematical model out of a real world problem.

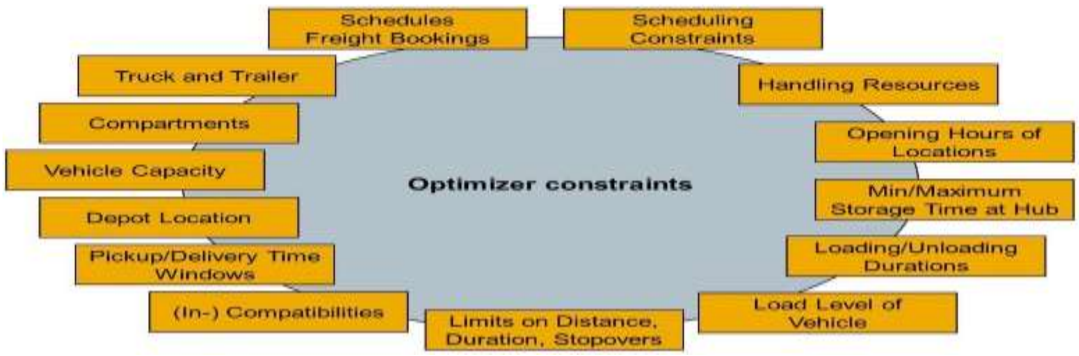
SAP TM's optimizer engine, called Vehicle Scheduling and Resourcing (VSR), helps plan optimal shipments by considering resources and parameters like demand, capacities, schedules, and transportation costs. By default, the VSR strategy is used to optimize the inputs. SAP TM also provides a one-step or Shortcut planning strategy which enables carrier selection if configured per customer requirements.

SAP TM provides manual and automated tools for planning and optimization, letting you determine the best resources and routes. Transportation planners can reduce shipping costs by planning for inbound and outbound shipping across locations using VSR. One of the key objectives of Optimizer in SAP TM is freight unit consolidation and the creation of a cost-effective and timely route from source to destination that minimizes total costs and satisfies all constraints (hard and soft) as highlighted below.

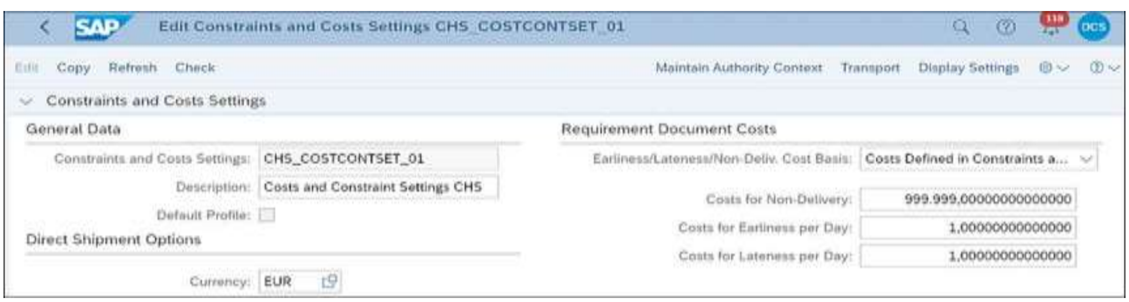
4.2. Costs and Constraints

The optimizer aims to minimize the overall expense, which comprises a weighted combination of the following components:

1) Non-delivery/execution penalty (per freight unit (FU))
2) Earliness and lateness penalty (per FU)
3) Fixed cost (per vehicle or route)
4) Travel-dependent costs (per vehicle), for example, distance and duration.
5) Load-dependent costs (per vehicle and route)
6) Sustainability costs such as CO2 emissions



Below is a SAP TM screenshot of Optimizer constraints and cost settings.



VSR rule-based algorithm minimizes the total costs in the optimization run while adhering to the hard constraints. Typically, hard constraints can be classified as the loading capacities of a vehicle resource. Soft constraints, on the other hand, are categorized as Requirement dates/times of freight units. VSR optimization can also schedule a freight unit after the requested delivery date. In this case, delay costs are incurred. Route-based and destination-based distance costs can yield different results. For instance, in North America, destination-based distance cost calculation is used frequently, whereas, in Europe, route-based distance costs are primarily used [10].

The following table shows the planning data that VSR optimization considers as constraints:

Planning Data	Constraint	Comments
Handling resources for loading and unloading as well as operating time	Hard	In addition to the operating times, VSR optimization also considers loading capacities for the handling resources.
Incompatibilities	Hard	Dangerous goods per EPA regulations

Planning Data	Constraint	Comments
Pickup/Drop	Soft / Hard	VSR optimization can also schedule the pickup of the freight unit before or after the requested pick-up date/time. In this case, earliness or delay costs are incurred. You can define tolerances for premature or delayed pickup without penalty costs.
Loading and unloading durations	Hard	In the case of schedule-based freight orders and freight bookings, the system does not consider loading and unloading durations.

4.3 Rough Cut Planning

Rough Cut Planning in SAP TM Optimizer is a feature designed to help organizations make preliminary, high-level planning decisions based on simplified data. This process is beneficial in the early stages of transportation planning when detailed information may not yet be available or when quick, strategic decisions are required [8][9]. The key goal here is to provide a quick assessment and feasibility of available resources, and load volumes per transportation requirements to enable planning. It helps in assessing future capacity needs, budget forecasting, and long-term strategic alignment.

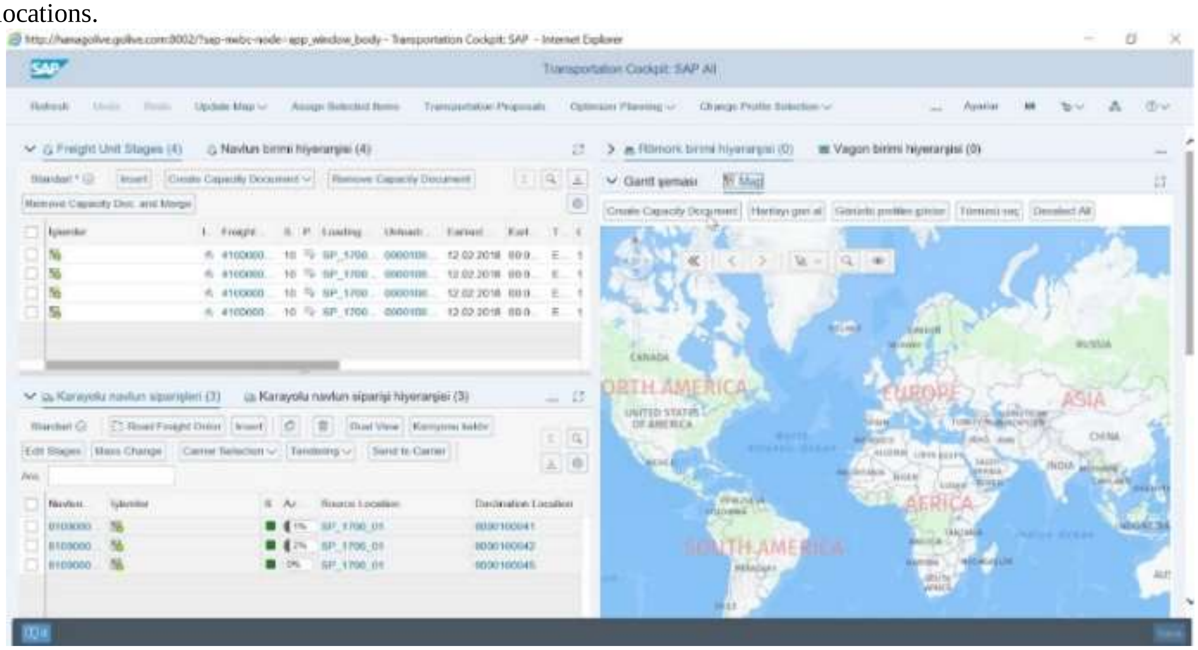
There are some instances where transportation planners are not looking for detailed planning and rough planning without setting up master data such as transportation lanes. For instance, in the case when the main stage (ocean, air, rail, etc.) needs to be planned, but the truck pre- and on-carriage planning is done later and even by a different user or organization at times, the planner can use Optimizer for rough cut planning by making few cosmetic changes in settings.

Since rough-cut planning is a high-level overview, it often leads to inaccuracies in planning and forecasting which the Optimizer algorithm can help manage better. The optimizer allows for the adjustment of variables, historical data, and industry benchmarks to maximize resource allocation while adhering to cost and capacity constraints [12]. This integration reduces the risk of errors and ensures that the strategic insights from rough-cut planning are effectively translated into operational plans.

Another key challenge with rough-cut planning is that it cannot manage existing market conditions, and supply chain disruptions due to unforeseen macroeconomic or global events. The optimizer offers robust simulation capabilities, enabling companies to model different market scenarios and understand potential impacts on their logistics network. This feature helps in planning for contingencies and building resilience into the transportation strategy.

5. Transportation Cockpit (TNC)

Even though the transportation cockpit is not the topic of this paper, I want to briefly touch upon this feature as it is the heart and key user interface of SAP TM Planning (manual and automatic via Optimizer). The TNC provides a comprehensive view of all transportation activities, including inbound and outbound shipments. Users can use the TNC to Transportation lanes, carriers, and delivery locations.



6. Performance Challenges in Optimizer

Typically, SAP Optimizer is fast when selected for a couple of freight units for planning, but there are instances where the optimizer may run for hours to execute the rules via the algorithm, depending on the configuration. Since transportation planners have limited time, it is imperative to make pertinent changes in SAP Configurations to provide optimal results with less complex settings, shorter run time, or for a complete replanning, considering all complexity.

1) Optimizer helps to break problems into smaller parts to resolve. To cover 50 places, for example, a single transportation mode would need to assess 2500 pairs of locations. However, if the problem is split up into 5 smaller sub-problems, each with 10 locations, the computation only needs 500 pairs. As a result, just 20% of the possible outcomes remain. To effectively handle this in conjunction with functional TM specialists, the SAP Basis team can assist by adjusting the optimizer settings [8].

2) The quantity of transportation options has a significant influence since it is one of the optimizer's most fundamental parameters. Every mode of transportation will generate more options, which will lower performance overall and in terms of memory usage. Reducing the means of travel is crucial for performance because each one will hold the transportation lane information, which is the major memory expense.

3) The distances between the places are expressed in terms of transportation lanes. Based on the specified requirements, only lanes that are available and necessary should be maintained to get better outcomes. Zone formation can be used to reduce data and calculations if there are several locations in the same area [8,14]. Applying filters according to client specifications helps speed up rule engine execution.

4) Locations can also be defined using reference coordinates. Nearby sites can be described in the same reference coordinate as in zone logic even at long distances. The crucial aspect in this case is keeping the reference coordinate centrally so that it can be used to denote many locations. To obtain precise coordinates, GIS integration will be required [8,10,13].

5) Incompatibilities can be employed to restrict the criteria or data selections that are acceptable for the optimizer to apply in solving the optimization issue. To avoid assigning freight units to specific resources or to utilize transshipment locations, for instance [8,11,14], it might be employed. Every compatibility that is utilized to lower the number of resources will improve the optimizer's performance.

The table below highlights a comparison of optimizer runs for a large US-based Consumer Product Goods manufacturer. Planning with an optimizer run led to savings of $2M per month and created an improvement of 20% on the customer satisfaction scale which fostered trust in customers thereby leading to increased sales and revenue [5][6].

Metric	**Planning without Optimizer**	**Planning with Optimizer**	**Savings/Improvement**
Cost	$10M/month	$8M/month	20% reduction
CSAT Score	75%	90%	20% improvement
Route efficiency	70%	85%	10% improvement
Delivery Times	4 days on average	3 days on average	25% reduction
CO2 Footprint	5000 tons of CO2	4000 tons of CO2	20% reduction
Fleet Utilization	80%	90%	12.5% improvement
Expedited Shipments	100,000 per month	60,000 per month	40% reduction
On-time delivery rate	80%	95%	19% improvement
Operational Errors	5% error rate	2% error rate	60% reduction

This manufacturer achieved better results due to planning with an optimizer for multiple constraints such as vehicle, driver, load, carrier, route, and carbon footprint. Optimizer helps standardize the key planning parameters and constraints such as volatile volumes (full truck vs. less than truckload), dynamic routing, load planning, and carbon footprint. This helps optimizer simplify complex problems and save costs for organizations of all sizes.

7. Benefits of Optimizer

The SAP TM Optimizer extends the capability further by assisting businesses to find the best plan for executing their transportation operations. This tool utilizes algorithms, such as constraint programs, to derive optimal solutions for transportation plans subject to specified business constraints and rules.

Some of the detailed benefits of TM Optimizer are as under -

1) **Reduced Transportation Costs**: Transportation planners can optimize routes, loads, shipments, and the best modes of transport, to significantly lower their expenses related to fuel, tolls, and carrier costs.

2) **Visibility and Control**: Optimizer provides detailed insights and visibility into route selection, vehicle loads, driver schedules, and resource capacity thereby providing better visibility and control of overall transportation network activities.

3) **Resource Utilization** – Optimizer facilitates maximizing the utilization of resources, planning full truckload (FTL), reducing the number of trips, and factoring in driver's shift schedule and working times resulting in higher and more economical resource utilization.

4) **Efficient Service levels** – Optimized routes and selection criteria during planning imply that goods would get shipped and received at destinations effectively thereby enhancing service levels and customer satisfaction score [15].

5) **Advanced Analytics and Reporting** – To continuously improve business processes and performance, SAP TM Optimizer can generate multiple reports on key performance indicators to facilitate informed decision-making.

6) **Sustainability**—Optimizer is one of the key drivers in reducing the carbon footprint of logistics operations. Planners select efficient routes and fuller loads with fewer diversions, reducing emissions. This helps businesses meet their scope 3 emissions and sustainability goals at the corporate level.

8. Future Research in Optimization

As Generative AI technology becomes more pervasive, the scope for advanced research in TM Optimization increases manifold. Machine learning algorithms can tailor transportation planning based on customer preferences and behavior in the next two years or less. Routing efficiency can be further improved by training models based on historical data in the optimizer. This will enable companies to optimize route and service personalization to dynamically adjust optimizer settings to improve lead times and customer satisfaction scores.

Conventional models cannot cope with large-scale route planning, load optimization, or multi-modal transportation. The exploration of quantum computing for solving computationally intensive optimization parameters is a subject of research interest in the TM domain. Integrating the Internet of Things (IoT) sensors and devices for real-time tracking of vehicles, shipments, traffic, weather, and environmental conditions is another avenue of research and development for industry practitioners. IoT sensors are instrumental in gathering data from vehicles to predict maintenance or breakdown needs thereby preventing inordinate delays [14]. This data can feed into TM systems to enable more precise and adaptive optimization for transportation planners to bake into their decision-making and simulations.

Another area for improvement and research would be selection settings in case of carrier selection or load consolidation as Optimizer would be able to stack and prioritize load based on cost savings, service levels, and environmental impact. Planning strategically and consolidating load via optimizer would further aid in organizations' decarbonization and sustainability imperatives as fuel costs and CO2e emissions can be anticipated accurately.

Finally, collaborative logistical platforms with ecosystem partners are another subject of research areas to share historical data without compromising privacy and glean actionable insights from emerging data patterns that can benefit the logistical sector at large.

9. Conclusion

One of the biggest challenges in the supply chain industry is the limited visibility and resilience to disruptions. By integrating real-time data, tracking, and tracing through IoT devices and sensors on vehicles and shipments, transportation planners gain actionable insights. These tools allow them to identify and analyze patterns in transportation data, enabling smarter, more proactive decision-making.

Leveraging the SAP TM Optimizer model yields many valuable benefits for organizations as it is not just about accurate planning or savings tools but is more of a strategic tool and needs to be aligned with long-term business goals. For example, by improving delivery lead times and service quality, companies can strengthen their brand reputation and customer loyalty and improve customer satisfaction score (CSAT). Supply Chain Control Tower (with embedded TM data, and augmented analytics) offers a centralized view of the entire logistics network. Planners can glean predictive insights from machine learning models thereby enabling faster response and adaptability to incidents, to ensure operations continuity.

For supply chains to be resilient and nondisruptive, flexibility, adaptability and agility are key levers, and Optimizer enables businesses to adapt their strategies in the wake of market volatility, fuel fluctuations, or new regulatory and compliance events[15]. With a rising focus on global emissions and their impact on the environment, Optimizer supports Sustainable practices by selecting green carriers and optimizing routes and loads to minimize fuel consumption, emissions, unnecessary trips for drivers, etc. Businesses can reduce carbon footprint reduction and align with global sustainability standards.

In conclusion, the insights provided by Optimizer help empower decision-makers at both tactical and strategic layers of management. With up-to-date information on transportation performance, costs, and opportunities for improvement, planners can make informed decisions that optimize performance across the board.

10. References

[1] https://www.gartner.com/reviews/market/transportation-management-systems

[2] Ritzmann, A., et al. (2016). Advances in Transportation Management Optimization: Integrating Optimization Methods with TMS for Cost Reduction and Service Quality Improvement. Transportation Research Procedia, 15, 417-426.

[3] Chopra, S., & Meindl, P. (2020). Transportation Management Optimization: Enhancing Efficiency through Advanced Algorithms. Journal of Transport Management, 25(3), 301-315.

[4] Jula, P., & Schiefer, G. (2018). Integration of SAP TM with ERP Systems: A Case Study on Seamless Coordination in Transportation Planning. International Journal of Logistics Management, 29(2), 563-581.

[5] https://leverx.com/case-studies/sap-tm-implementation-for-large-retailer

[6] https://www.mcleodsoftware.com/

[7] https://help.sap.com/docs/SAP_TRANSPORTATION_MANAGEMENT/54cf405c9d9e4c96bf091967ea29d6a7/4a5a56e958b14204b9d9a65fed58ea6f.html

[8] https://archlynk.com/blog/secrets-of-the-sap-transportation-management-optimizer

[9] https://xpertminds.net/sap-transportation-management-optimizer-demystified/

[10] https://community.sap.com/t5/enterprise-resource-planning-blogs-by-members/capability-of-optimizer-planning-without-transportation-lane-in-s-4hana/ba-p/13483934

[11] https://sapinsider.org/analyst-insights/minimizing-route-optimization-model-run-times-in-sap-tm/

[12] https://blog.sap-press.com/the-carrier-selection-optimizer-in-sap-for-goods-carrier-selection

[13] https://community.sap.com/t5/supply-chain-management-blogs-by-sap/sap-tm-optimizer-performance-an-abap-developer-s-point-of-view/ba-p/13179400

[14] https://www.scmchamps.com/blog/maximize-transportation-efficiency-with-sap-tm-route-optimization

[15] https://ortec.com/en/featured-insights/insights/pallet-load-building-sap-transportation-management