Dispatch Optimization in Bulk Tanker Transport Operations

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Introduction

- Established in 1935

- Broad portfolio of services: Regional trucking,long-haul, bulk, supply chain management, warehousing or cross-border.

- Accepts 350 customer orders per day, involving 10000 distinct commodities with pickup and delivery locations across the continental United States.

Bulk Division
Transport of Chemicals and Fuels

1000 Drivers

+190 facilities worldwide

1600 Tank Trailers

1800 Orders per week

Annual revenue: $5 billion

6M Miles per month

Dispatch Optimization in Bulk Tanker Transport Operations

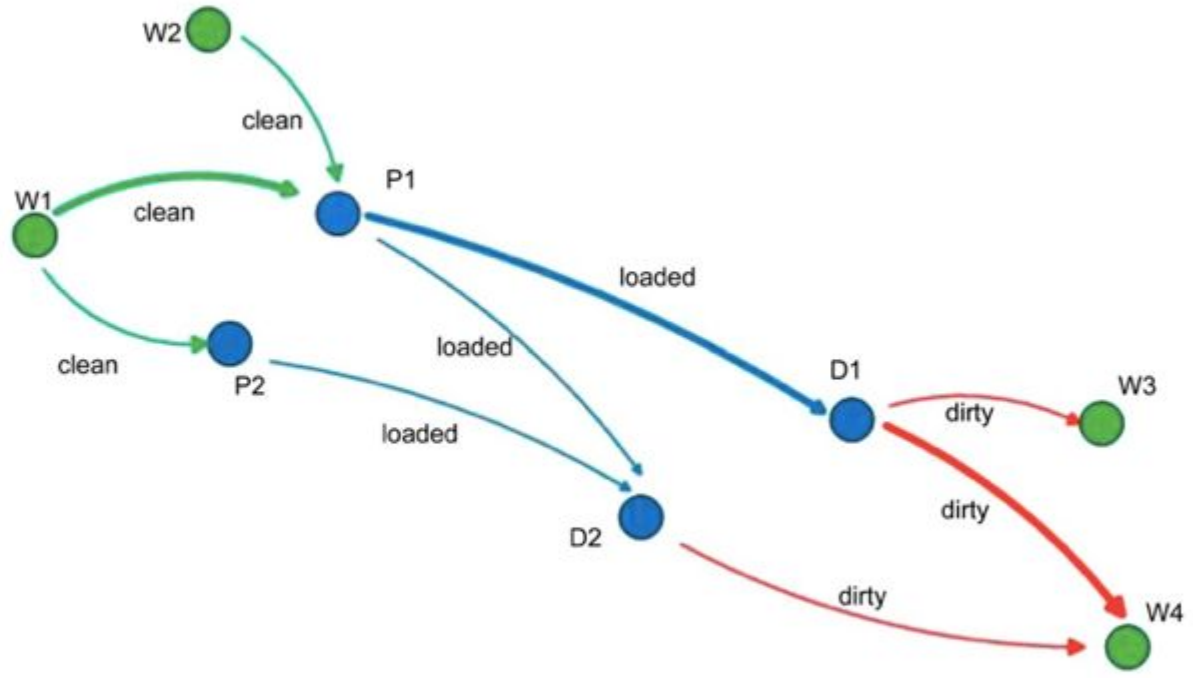
- Transport of liquid-chemical products and fuels with bulk tanker trailers

- Complicating factors:

1. prevention of hazardous interactions between different commodities

2. the washing and cleaning of tanker compartments between orders.

Dispatch Optimization in Bulk Tanker Transport Operations



The Geographic Distribution of Customer and Tank Wash Facility Locations

•Schneider National currently has approximately 9,000 distinct customer and consignee locations.
•150 active wash facilities vary in both handling-capacity size and wash capability

(a)

(b)

Tank Choice Decision

1. Determining a collection of cleaned tanker trailers that are compatible with order requirements
2. Checking whether previous contents of the tanker meet compatibility rules relative to the prospective contents
3. Selecting a tank wash location where such tankers will be available
4. Selecting a second tank wash location at which the selected trailer will be washed for a subsequent order.

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Problem Definition

- Chemical-interaction properties of these commodities impose complex product-sequencing constraints

- Tanker trailers must be routed to independent facilities where they are washed and prepared for their next use.

- Customer-specific requirements also drive prior product (i.e., previous commodities that have been in the tank)

Problem Definition

•At most customer locations, loading or unloading may take several hours to a day or longer. Consequently, most orders require two or more distinct driver assignments so that drivers do not incur undue idle time.

•Driver- assignment options are evaluated for cost and feasibility.

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Objectives

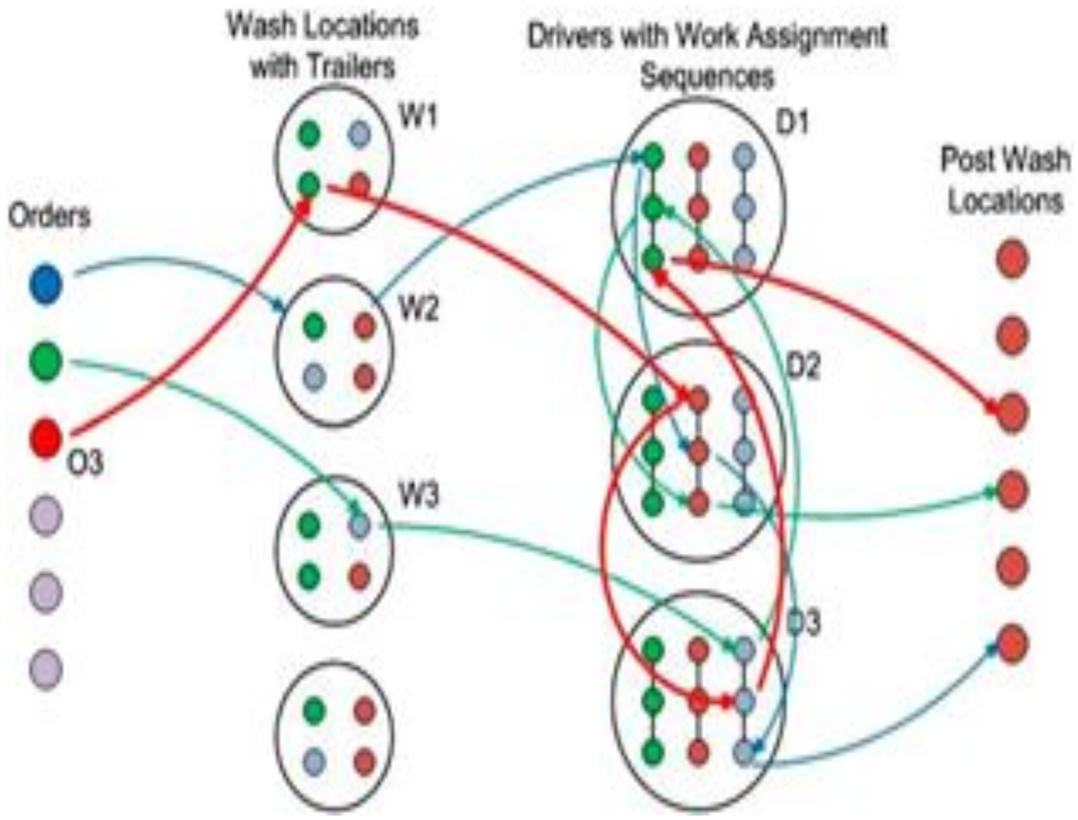
•Determining optimal (and near-optimal) solutions from the feasible combinations that are identified.

•Minimizing unproductive driver activity, while ensuring that driver work rules and other considerations are met.

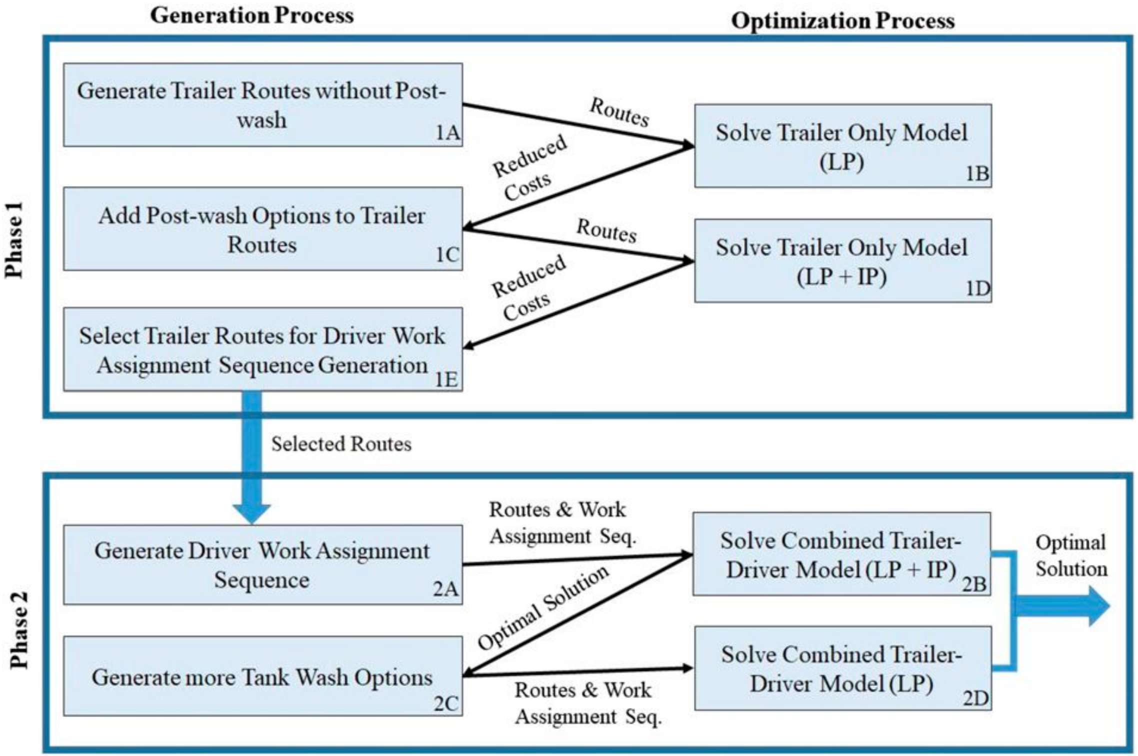
Assignment Decisions required for an order are:

1. a specific tanker trailer and the prewash facility assignment
2. a potentially different driver and trailer assignment to execute each move
3. the post wash facility to which the trailer will be repositioned after delivery of the product to the customer.

A map can be seen for all the assignments mentioned above in the adjacent section.



The Solution Technique Multiple Phased Generation and Optimization Processes



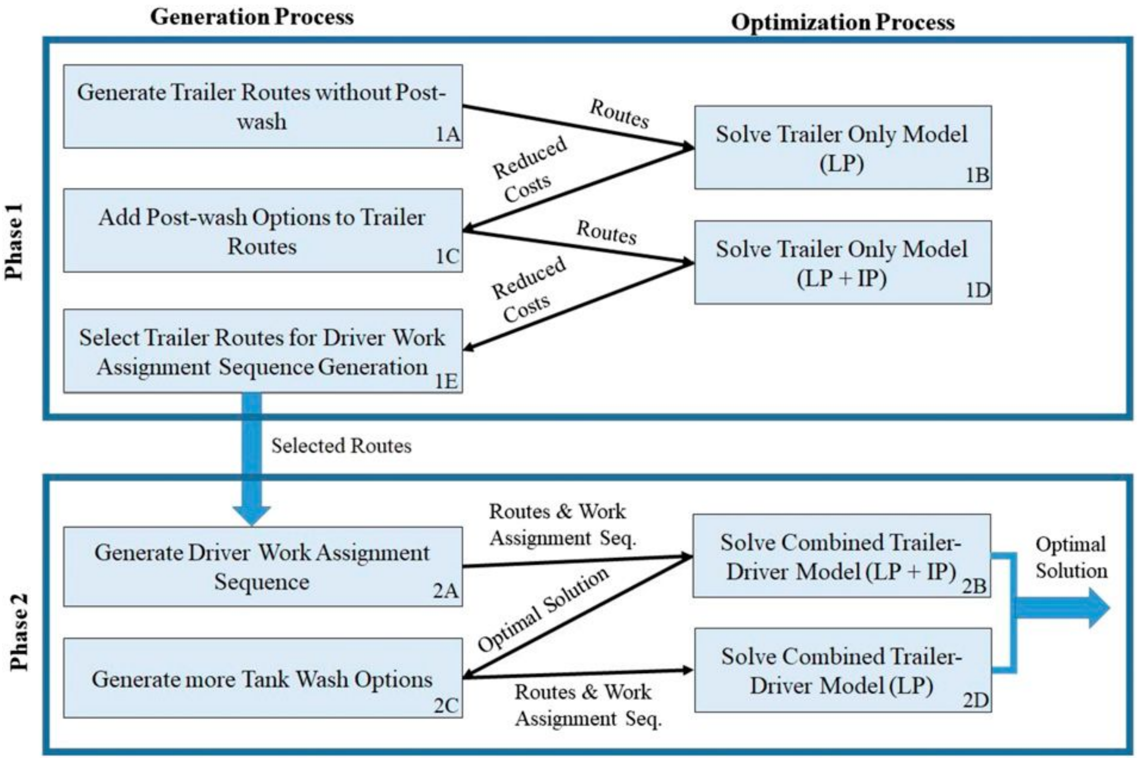
1)Tanker Trailer Feasibility

The first step of the solution process is to determine the set of feasible, available tanker trailers, which depends on the chemical composition of products, customer requirements, and intervening wash cycles.

2)Trailer Route Generation

To limit the number of routes, we consider prewash location options, but postwash choices are deferred unless they are internal to a multiple-order assignment.

Phase 1 continued



3)Trailer Route Optimization

The optimization model minimizes the total cost of the route while ensuring the following constraints: (1) each order and trailer can be assigned to at most one route, (2) capacity at the tank washes should not be exceeded on a given day or week, and (3) number of trailers of a given type meet the minimum and maximum requirements for each region. We generate postwash options for the best several hundred thousand feasible options based on reduced costs from this LP relaxation.

Phase 2: Assign drivers to the routes

Driver Work-Assignment Schedule Generation

Phase2 in the optimization process includes finding feasible drivers and corresponding costs to execute the candidate trailer order combinations. Next, the set of available drivers is evaluated against each work assignment to find feasible driver work-assignment combinations, called driver work- assignment schedules. This again resembles with a heuristic approach.

Combined Trailer Driver Optimization

The model requires that each driver be associated with at most one work assignment sequence and links constraints between driver work assignments and the relevant trailer.

Sets, Decision Variables and Parameters

Set of Equipment Routes

e: Set of routes for equipment $e \in \xi$

o: Set of routes that cover order $o \in O$,

w: Set of routes that use wash $w \in W$

g: Union of routes for equipment contained in group $g \in G$

$t \in T$, index the sequence of periods

Decision Variables and Parameters

x_i: 1, if equipment route i is selected

0, otherwise

B_o: penalty cost for not covering order o with any equipment route

ξ_o: slack variable associated with not covering order o with any equipment route

$B_{w,t}$: penalty cost of exceeding the tank-wash capacity at period t

Sets, Decision Variables and Parameters

$E_{w,t}$: slack variable associated with exceeding tank wash capacity K

$K_{w,t}$: the tank-wash capacity at tank wash w at period t, respectively

$\theta^L{}_{g,w}$:lower threshold for equipment group

$\theta^U{}_{g,w}$:upper threshold for equipment group

$B^L{}_{g,w}$ and $B^U{}_{g,w}$ are the penalty costs associated with lower threshold $\theta^L{}_{g,w}$ and upper threshold $\theta^U{}_{g,w}$, respectively

$\xi^L{}_{g,t}$,$\xi^U{}_{g,w}$ are the corresponding slack variables of the penalty cost due to tresholds

Trailer Optimization

The model minimizes:

1. total cost of the route
2. total penalty cost for not covering an order by any equipment route
3. total penalty cost for exceeding the tank-wash capacity
4. the total penalty cost for not meeting the lower and upper thresholds of equipment group at a tank-wash

Constraints:

1. we can only have one route scheduled for each e
2. each order o is either assigned to a route or incurs a penalty cost
3. enforces tank-wash capacity $K_{w,t}$ for tank wash w for each period t

For each equipment group g:

4. a minimum threshold $\theta^L_{g,w}$ and
5. maximum threshold $\theta^U_{g,w}$ must arrive at the tank wash w at the end of time t

$$TO: \min \quad z_1 = \sum_{i \in \mathcal{R}} C_i x_i + \sum_{o \in \mathcal{O}} B_o \xi_o + \sum_{\substack{w \in \mathcal{W} \\ t \in \mathcal{T}}} B_{w,t} \xi_{w,t} + \sum_{g \in \mathcal{G}, w \in \mathcal{W}} \left(B^L_{g,w} \xi^L_{g,w} + B^U_{g,w} \xi^U_{g,w} \right).$$

Subject to

$$\sum_{r_e \in \mathcal{R}^e} x_{r_e} + \xi_e = 1, \forall e \in \mathcal{E}$$

$$\sum_{r_o \in \mathcal{R}^o} x_{r_o} + \xi_o = 1, \forall o \in \mathcal{O}$$

$$\sum_{r_w \in \mathcal{R}^w} x_{r_w} - \xi_{w,t} \leq K_{w,t} \; \forall w \in \mathcal{W}, \forall t \in \mathcal{T}$$

$$\sum_{r_{g,w} \in \mathcal{R}^g \cap \mathcal{R}^w} x_{r_{g,w}} + \xi^L_{g,w} \geq \theta^L_{g,w}, \forall g \in \mathcal{G}, \forall w \in \mathcal{W}$$

$$\sum_{r_{g,w} \in \mathcal{R}^g \cap \mathcal{R}^W} x_{r_{g,w}} + \xi^U_{g,w} \leq \theta^U_{g,w}, \forall g \in \mathcal{G}, \forall w \in \mathcal{W}.$$

Sets, Decision Variables and Parameters

s: Set of work assignments $s \in S$
d: Set of drivers $d \in D$,
ω_d: Set of walks for driver d $\omega \in \Omega$

Ω^d:collection of candidate work-assignment sequences for driver d $\Omega^d \in \Omega$
Ω^s:collection of candidate work-assignment that contain work assignment s $\Omega^s \in \Omega$
Ω^i:collection of work-assignment sequences that intersect equipment route i $\Omega^d \in \Omega$

Decision Variables and Parameters
y_j: 1, if driver work-assignment j is selected
0, otherwise

$C_{\omega,d}$: cost of driver work-assignment sequence

ξ_s: slack variable related to penalty for not covering work assignment s with any driver
ξ_d: slack variable related to penalty for leaving a driver idle

Driver Optimization

The model minimizes:

- trailer optimization cost
- the total cost of selected driver work-assignment sequences (including penalty and (or) bonus costs)
- penalty for leaving an available driver idle

Constraints:

1st, 2nd, 3rd, 4th, and 5th constraints are the trailer optimization constraints

6. driver d can only have one driver work-assignment sequence scheduled
7. each work assignment s can be assigned to a route or it can be unscheduled
8. matches the driver work assignments to the corresponding equipment routes

$$DO: \min \quad z_2 = z_1 + \sum_{j \in \Omega} C_j y_j + \sum_{s_1 \in \mathcal{S}} B_s \xi_s + \sum_{d \in \mathcal{D}} B_d \xi_d$$

Subject to

$$\sum_{r_e \in \mathcal{R}^e} x_{r_e} + \xi_e = 1, \forall e \in \mathcal{E}$$

$$\sum_{r_o \in \mathcal{R}^o} x_{r_o} + \xi_o = 1, \forall o \in \mathcal{O}$$

$$\sum_{r_w \in \mathcal{R}^w} x_{r_w} - \xi_{w,t} \leq K_{w,t} \ \forall w \in \mathcal{W}, \forall t \in \mathcal{T}$$

$$\sum_{r_{g,w} \in \mathcal{R}^g \cap \mathcal{R}^W} x_{r_{g,w}} + \xi^L_{g,w} \geq \theta^L_{g,w}, \forall g \in \mathcal{G}, \forall w \in \mathcal{W}$$

$$\sum_{r_{g,w} \in \mathcal{R}^g \cap \mathcal{R}^w} x_{r_{g,w}} + \xi^U_{g,w} \leq \theta^U_{g,w}, \forall g \in \mathcal{G}, \forall w \in \mathcal{W}$$

$$\sum_{\omega_d \in \Omega^d} y_{\omega_d} + \xi_d = 1, \forall d \in \mathcal{D}$$

$$\sum_{\omega_s \in \Omega^s} y_{\omega_s} + \xi_s = 1, \forall s \in \mathcal{S}$$

$$\sum_{\omega_i \in \Omega^i} y_{\omega_i} \leq m x_i, \forall i \in \mathcal{R}, m \text{ sufficiently large}$$

Suggested Improvements on Trailer Optimization Model

Depending on our research for similar dispatching systems, 2-Exchange/Swap Algorithm for inter-route improvement can be utilized for this dynamic dispatching system [1], [2].

Exchanging wash centers between routes and comparing transhipment cost can be a way to reduce cost. This can be applied on both within prewash center and post wash centers [1].

All possible locations for washing centers must be exchanged and then after a cost comparison, choose the washing centers for each washing route with the lowest cost.

Advantages and Disadvantages of Inter Route Improvement Heuristic

Advantages of this heuristic is that it is simple to implement and it can reduce the total number of tankers needed for the routes.

Disadvantages of this heuristic is that it takes time to reallocate new washing centers.

Moreover, the overall assignment process for trailer routes of washing centers is an heuristic rather than true optimization because some certain clusters of prewash centers are only considered hence this prunes (locally) unpromising candidates, but do not guarantee that such a candidate would not be in an optimal solution.

Business Benefits and Challenges

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Nonrevenue Miles Reduction

- reduction of over 1 million nonbillable miles annually
- also seen a significant reduction in the volatility of nonbillable miles

Driver Productivity Improvement

- the dispatch system optimizes the selection and scheduling of drivers to service
- significant decrease in the number of miles that need to be driven
- $2.5 million in additional annual revenue.

Business Benefits and Challenges

Unused Hours

- reduction of unused driver time of 2.5 hours per shipment
- $1.8 million additional annual earnings before interest and taxes

Better Equipment Optimization:

Approximately 12,000 additional days of trailer capacity availability per year, effectively adding 60 trailers to the fleet at no additional cost

Prior-Product Validation:

Feasible trailer identification and verification would take 30 minutes, now completes in 3–5 minutes. This translates to several thousand person-hours per year.

Business Benefits and Challenges

Planner Productivity Improvement

- 28% productivity improvement
- the greater advantage is in allowing associates more time to focus on problems and complex issues that need attention
- the goal is to achieve 80%–90% compliance with model recommendations
- additional productivity gains when associates have gained expertise with the new processes

Business Benefits and Challenges

Improved Customer Experience

Trailer rejections for incompatible prior products have been reduced substantially and customer feedback has been strongly positive

Order-Acceptance Response Time

New system has enabled quicker and more accurate visibility to available and projected capability. This has led to a reduction in the time required to make an acceptance decision.

BUSINESS BENEFITS

Realized Annually

$2.4 M (1.2 M miles)
Non-revenue miles reduction

$2.5 M
Additional revenue due to improved driver productivity

$1.8 M EBIT
Drivers -- fewer unused hours / improved retention

12,000 additional days
Trailer utilization

+ 28%
Planner productivity

2 FTE + error reduction
Prior product checking

Improved
Customer experience

Reduced
Order acceptance response time

Planned Improvements

Relays

Implementing a network-design solution to determine a limited and fixed set of locations that will best service network freight flows, a real-time rerouting tool that will consider out- of-route (extra) miles, commodity and driver limitations, and relay location characteristics

Local Driver Optimization

Significant additional cost reductions and productivity improvements, particularly for local drivers, by introducing additional algorithmic enhancements

Planned Improvements

Integration with Demand Forecasts

More actively integrate location-selection evaluations with demand forecasting and order-acceptance processes.

Dynamic Wash Rebates

Large tank wash third-party vendors offer volume discounts, evaluating ways to incorporate these into the wash location choice

Conclusion

- The importance of building feedback mechanisms directly into the process rather than as an afterthought
- The system allowed business experts to focus on the 10% of dispatch planning work that requires human judgement and resolution of issues that are affected by factors that the automated processes cannot address.
- The decomposition approach initially separates the decision components (i.e., wash locations, tanker trailers, and drivers) and then combines them in a multiphase optimization framework, an innovative way to address and successfully solve

Examples From Turkey

Netlog - uses “Milk-Run” optimization

Omsan

Alışan Lojistik

Distribution planning of bulk lubricants at BP Turkey (Uzar, M. & Çatay, Bülent., 2012)

- minimize total transportation related costs
- assigning customer orders to the tanks and determining the routes of the tank simultaneously
- mixed integer linear programming

References

[1] K. Eldandrly, A. Ahmed, “Routing Problems: A Survey”, *ResearchGate.* Dec. 2010. Online. Available: https://www.researchgate.net/publication/236009566_Routing_Problems_A_Survey. [Accessed: Mar. 10, 2020].

[2] T. Du, F. K. Wang, P. Y. Lu, “A real-time vehicle-dispatching system for consolidating milk runs”, *ScienceDirect,* Vol. 43, Issue 5, pp.565-577, Sept. ,2007.