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Strategic Positioning of Empty Containers and Minimising Backhauls in Inland Supply Chain Network

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Abstract An end-to-end supply chain operation for inland logistics requires coordination and planning among various operations of import pickups, export delivery and empty container positioning for reuse and evacuations of unused containers through the ports. A major business goal of all these operations focuses on reducing the transport costs by utilizing maximum network capacity across active modes of hinterland transport. Designing an efficient network, ensuring that customer commitments are met with timely delivery of containers, is a complex and challenging task. In this paper, we explore optimization opportunities for an inland network with a heavy and unbalanced container traffic flow through its ports. We propose techniques for the strategic placement of empty resources, for optimal allocation at depots-terminals in the presence of time constraints. The novelties of our method include (i) strategic relocation of the resources to high demand areas, maximizing the resource utilization, (ii) triangulation of trucks to maximize available capacity in the network and minimize empty transport legs of round trips. For the empirical evaluation of the model, the inland network data for the North American region of a major shipping line is used. Though NAM specific data is used for the study, the proposed model can be generalised to any other geographical network with a similar set of business constraints.

Keywords transportation problem · empty resource positioning · network planning

1 Introduction

The liner shipping, the oldest and cheapest mode of transport is the backbone of global trade. The recent pandemic situation has further emphasized the importance of global transportation network of liner shipping along with a mandate to keep the local ports and terminals open to ensure the essential supply of food, fuel and medicine. A 30% fall in container volumes in China and a 9% reduction in global container volume during the three weeks spanning 20th Jan to 10th Feb 2020 along with the cancellation of about 105 sailings per month [1] during this pandemic has thrust importance of a resilient yet agile end-to-end supply chain.

Liner shipping, has always adapted to unexpected, predictable as well as unforeseen scenarios ever since 1956 when the container shipping began [2]. The disruptions caused by COVID19 pandemic has added a new dimension to the planning, positioning and execution space dominated by trade imbalance and hence container flows on specific trade routes. Further, trade uncertainties, disruptions and cancellations spanning weeks and months along with unreliable demand forecasts can lead further unplanned imbalance of empty containers in countries across trade routes. This scenario can complicate the already complex planning of empty containers and its evacuation which is a routine task, executed in all trade routes across geographical locations around the globe.

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The paper addresses the transportation problem for vehicle routing and scheduling with clustered backhauls of export pick-ups at the operational and tactical level, and positioning of empty containers for export pick-ups at the optimal location as a part of the strategic planning of an inter-modal transportation network.

In what follows, Section 2 outlines the Business Problem, Section 3 reviews the existing work in this area, Methodology and mathematical modelling detailed in Section 4 and Sections 5 respectively. Section 6 contains data, numerical analysis and the inferences. We summarise the research work in Section 7.

2 Business Problem

Positioning empty containers across ports, depots, warehouses, railway yards, terminals etc., collectively referred to as storage locations in this paper, is a routine process executed in a supply chain due to the trade imbalances in inflow and outflow of containers. In general, there is no accurate way of knowing the exact requirements of empty containers for positioning or evacuation. One could get an estimate by examining the past historical data of imports and exports during a specific period across geographical locations. There are some certainties for shipping companies concerning the inflow (imports) and outflow (exports) if their customers already have (i) a contract with them or (ii) a confirmed booking exists. In reality, many external factors affect the standard commodity flow patterns across different countries. Any fragility in economies due to an outbreak of pandemics as we experience now, unfortunate withering or excess due to the flourishing of seasonal crops and fruits or any diplomatic changes in trade relationships are some examples of external factors that can impact the trade flows in drastic ways.

It is important to make the empty containers available for the operational purpose of triangulation of import delivery containers with export pick up containers in case of deficits in supply. This is managed by the process of the movements of empty containers across various storage locations independently across the global network, thus balancing the surplus in one place with the deficit in other. Accumulated containers which have no scope of reuse will be eventually evacuated through identified terminals to respective trade lines.

This work addresses the business problem of planning the positioning of empty containers to the places of predicted demand for reuse or evacuation. The proposed two-phase planning strategy is outlined here. The first phase is the strategic planning and positioning of empty containers to meet the demand in the geographical neighbourhoods. The second phase focuses on optimizing the truck-container pickup-drop movements and re-usability of the empty containers across the import and export orders to minimize empty transport legs.

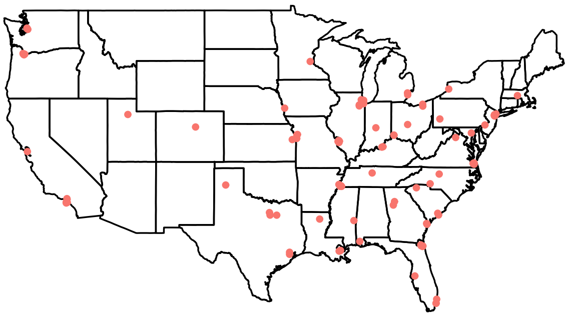


Fig. 1 Railyards identified across states.

The first phase pertains to the management of empty containers as unless placed at the right locations to combat the deficit, acts to drain the revenue. The second phase has the origin and destination locations defined and focuses on maximization of container utilization in the last mile by triangulation of trucks, thus balancing the demand deficits in these neighbourhoods for identified time windows. Data used for the study is weekly aggregates of import, export, empty containers movements in North America for the year 2019.

The geolocations in North America (NAM) where the empty containers can be positioned, foreseeing the inbound and outbound container flows are indicated in Fig. 1. The positioning of empty containers at strategic locations depending on dynamic requirements can minimise operational costs while triangulating the truck during the backhauls for next pickups. In the next section, we review literature specific to the transportation problems of vehicle routing and positioning of empty containers.

3 Literature Survey

The Vehicle Routing Problem (VRP) is known to be an NP-hard problem whose goal is to minimize the total routing cost in a network. Various customizations of these problems are used to model the supply chain routing scenarios for 3PL and 4PL service providers across various customers, terminals, warehouses, yards and depots in the shipping industry [20]. Diverse solution approaches include custom-fit heuristics, metaheuristics like Genetic Algorithms, Hybrid Tabu Search algorithms, Simulated or Deterministic Annealing algorithms which are widely used along with exact solution methods [19].

The VRP with Backhauls (VRPB) is a popular extension that saves an empty leg by reusing the same vehicle that delivers the cargo from an origin location to a destination for the transport of another set of cargos back to the origin location [12]. Many variations of VRPB are widely executed by various supply chain managers and in all cases, the deliveries have to be made before any scheduled picked ups. For full container load cargo loads Vehicle Routing Problem with Pickup and Delivery (VRPPD), Vehicle Routing Problem with Time Windows (VRPTW), Capacitated Vehicle Routing Problem (CVRP), Vehicle Routing Problem with Multiple Trips (VRPMT) are some popular flavours of VRP [15].

The solution space for exact, heuristics and metaheuristics approaches can address the network as a graph, using nodes for supply and demand and arcs to map the route (which can be multimodal – truck, rail, air, barge etc) that exists across the supply and demand nodes. Cost for travel per vehicle per unit distance can be assigned to the arcs of the graph. The cost of transport, in general, can be captured as haulage, holding and handling costs. Survey of literature indicates various the approaches to define objective functions- either the maximization of revenue (or utilisation, profits, meeting customer demands) or minimization of transportation cost (along with operational cost and risk) and some with a provision to penalize unmet demands [21,22,25].

A strategy for identifying new inland depots locations to help manage empty container positioning, regionally, thus minimizing the total system costs which are the cost of opening new depots and the repositioning cost of empties is proposed in work [7]. With the view that usually the container depots are located near the ports while the management of the empty containers is required near the customer location, the research work proposes a mathematical model to propose new depot locations near the New York-New Jersey port area. The work does not consider the routing of full containers either import drops or export pickups.

A mathematical model in a deterministic dynamic multimodal network, to minimise the overall cost of managing empty containers on an hourly time step, is proposed and validated using a commercial MIP solver of CPLEX [18]. The work of Tonci Caric et al. [10] proposes an integrated modelling and optimization framework for solving complex and practical relevant VRP which includes a script based modelling language, a library of VRP related algorithms and a GUI for easy interaction enabling fast and flexible prototyping of VRP.

In the presence of many specific solutions in the solution space of VRP, Vidal et al.'s unifying work in Multi-Attribute Vehicle Routing Problems (MAVRP), having studied and analysed in detail, 64 meta-heuristics methods, selected objectively for their outstanding performance on 15 classic Multi-Attribute Vehicle Routing Problems (MAVRP) [25], helps understand fundamental design elements to progress toward more generalist and efficient VRP algorithms. This work identifies "winning strategies" in designing effective heuristics for MAVRP, working on the categories of heuristic solution methods: constructive heuristics, local improvement heuristics, and metaheuristics, hybrid methods, and parallel and cooperative metaheuristics.

General-purpose heuristics use standard strategies of local improvement by a k-neighbourhood exploration or greedy algorithms for convergence to better local optima or both [8]. Some popular metaheuristics for the generic cases are evolutionary algorithms, ant colony algorithms, and various hybrid strategy algorithms with advantages of different methods [6, 9]. An optimization method for full and empty container movement supporting multimodal transport that is both truck and the railways in the hinterland is proposed in [21]. This work aims to maximize the revenue, with a penalty imposed for the unmet demand. The cost for an empty container movement is far less compared to the cost of a full container movement.

This work proposes a novel approach to solve the empty container deficit problem by recommending the positioning required at each depot based on the locational demand. In our work, the main focus is to satisfy every customer demand hence every export pickup has to be picked up either by a triangulated trip weaving in a line haul with a backhaul or by a specific round trip with an ongoing empty leg. In a similar approach, every import drop to a customer location is fulfilled, without an exception.

4 Methodology

We have seen in Section 2 that the efficient positioning of empty containers from locations of surplus to that of shortage at regular intervals is a task of high priority for the supply chain management. Inventory managers dynamically reposition them at regular intervals and allocate them to identified storage locations, depending upon future local requirements and existing policies.

In this paper, we propose a model for positioning empty containers in storage locations, for reusing for exports within a local neighbourhood. All the import drops after de-stuffing are either returned to nearby empty storage locations or reused for Export pick-up

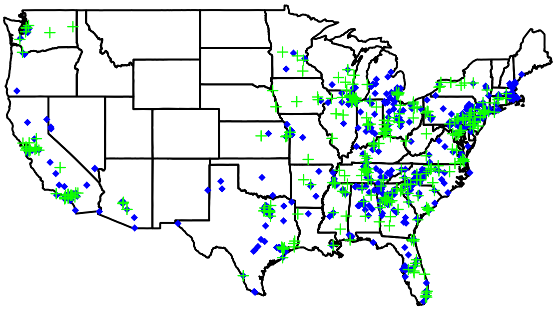


Fig. 2 Geolocation of import drops (green) and export pick-ups(blue) in a time slice 4

orders. Stocked up empty containers are used to match any deficit in supply at the neighbourhood. We identify import drops and export pick-up orders at a neighbourhood for a series of discrete-time slices $\varDelta = \{\delta_1, \delta_2, \ldots\}$.

We make two assumptions:

(i) Import containers after de-stuffing at any time slice δ_n can be reused for an export pick up in the next time slice δ_{n+1}.

(ii) Empty containers available in nearby cluster's identified storage location at any time slice δ_n can be reused for an export pick up in the same time slice δ_n.

The empty containers can be made available at respective clusters ahead of time if there is access to the booking data on export pick-ups and import delivery in each of the clusters as strategic planning. Fig 2 indicates the import drop locations and export pickup locations at time slice δ_4

In the first phase, we identify the available estimates for the time slices $\varDelta$ for the following: (i) customer demands for export pick-ups, (ii) import containers reaching the neighbourhood (iii) import containers that can be triangulated for export pick-ups, (iv) empty containers returning to warehouse-depots, for every selected neighbourhood of NAM region. The whole NAM area is partitioned to sets of clusters to ensure the geographic proximity of the locations. Clustering demonstrated in this paper is location-proximity-wise partitioning, though any partitioning would be sufficient for the execution of the mode. The partitioning enables strategic planning of empty back-hauls for triangulation possibilities within the same neighbourhood depending upon the governing systems. There are a finite number of clusters which do not overlap with each other for a specific time slice of δ after partitioning process. The

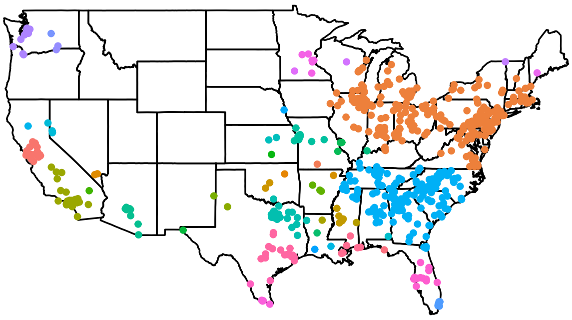


Fig. 3 Geolocation clustering, NAM.

import drops locations and export pickup locations are clustered using the City Clustering Algorithm [16].

The demand and supply of the containers at the neighbourhoods at the time slices are real data available from import and export bookings. Empty container availability is based on the inland depots safety stock. We also assume that that the containers available at the beginning of the time slice are ready for the pick up thus adjusting the lead-times for inland positioning across multiple depots. The model specified here is very generic and processes are separated at various stages such that it can be extended to various container types, mode of travels, and appointment window date and time.

The clustering approaches explored for this research work includes DBScan, Hierarchical clustering, LeaderCluster and the finally selected City Clustering Approach. City clustering approach works on the great circle distance and works on the maximum distance for grouping which in this case is set to 120Kms (approx. 75miles). Fig. 3 illustrates the result of the CCA on the geolocations involved in the import drops and export pickups for a selected time slice.

In the next section we present a mathematical model to explore how best can we position the empty containers at the depot or yard level knowing the import returns and the export pickup orders at a specific neighbourhood for a specific time slice based for NAM region.

5 Mathematical Model

The business problem deals with the dispatching of vehicles between different locations depending upon the demands and supply which are dynamic with time. Routing decision-making models that balance the supply and demand in a network [17], optimization and rolling horizon algorithms that update the static solutions with varying demand-supply values [5,26] are some practical approaches. Further, mathematical formulations using column generation methods [4], custom branching algorithms [11] or constraint programming [6,26] are some standard practices. Here we detail a mixed-integer programming approach to optimally solve the transportation assignment problem in a dynamic network.

Table 1 describes the variables and parameters used in the mathematical model. The set of origin-nodes O (destination-nodes D) provides the supply (demand) for the network at every time slice δ. Note that the Import drops from the previous time slice $\delta - 1$ can be reused as a source in the current time slice δ. Origins and destinations are collectively addressed as 'nodes' of the network and the transportation links (here roads) are denoted as the 'arcs' of the network.

The arcs are assigned individual capacities $w_{i,j,\delta} \forall i \in O, j \in D$ and $\delta \in \varDelta$. For the numerical analysis demonstrated in section 6.2 we have assumed a large integer $U \geq max\{w_{i,j,\delta}\}, \forall i \in O, j \in D, \delta \in \varDelta$ as an upper bound for the arc capacities to enable a standard business condition that the demand at any destination node can be routed via an existing arc that connects it to a source node, given availability at that source node.

The model proposed here is based on the transportation problems in network flows [3] and it can efficiently use the specific structure of a graphical networks without extensive computational resources to generate an optimal solution.

5.1 MIP model formulation

$$\min \sum_{i \in O} \sum_{j \in D} c_{i,j,\delta} x_{i,j,\delta} \tag{1}$$

$$s.t. \sum_{j \in D} x_{i,j,\delta} \leq a_{i,\delta} \qquad \forall i \in O, \forall \delta \in \varDelta \tag{2}$$

$$\sum_{i \in O} -1.x_{i,j,\delta} = -1.b_{j,\delta} \qquad \forall j \in D, \forall \delta \in \varDelta \tag{3}$$

$$x_{i,j,\delta} \in \mathbb{N} \qquad \forall i \in O, j \in D, \forall \delta \in \varDelta \tag{4}$$

$$0 \leq x_{i,j,\delta} \leq w_{i,j,\delta} \qquad \forall i \in O, j \in D, \forall \delta \in \varDelta \tag{5}$$

The objective function (1) minimizes the total cost of empty container transportations between the origin-destination pairs (i, j) for a time-slice $\delta \in \varDelta$, for empty positioning locations $i \in O$ and export pick up locations $j \in D$. Constraints (2) ensures that the empty containers available at the positioning warehouse locations (along with the reusable empty containers after the export drops from the previous time slice) $i \in O$ are sufficient to meet the demand at each of those locations in a cluster. Constraints (3) ensures that the number of containers reaching the location $j \in D$ from all possible resources does not exceed the requirement at that location. Finally, (4) defines the variable domains and (5) defines the upper-bound on the decision variables.

Table 1 Definitions: Mathematical Model Inputs

Sets	
S	Set of import drop locations
D	Set of export pickup locations
P	Set of empty positioning locations
$\varDelta$	Set of time slices
O	Set of pickup origin locations for empty container, $O \subset \{P(\delta) \cup I(\delta - 1)\}$
D	Set of drop destination location for empty container, $D \subset E(\delta)$
A	Set of feasible arcs {(i,j,δ)} that is formed in the network, where $i \in O$ and $j \in D$ and $\delta \in \varDelta$.
Parameters	
m_δ	Total number pickup origin locations in set $O, \forall \delta \in \varDelta$
n_δ	Total number of drop destination locations in the set $D, \forall \delta \in \varDelta$
$c_{i,j,\delta}$	Transportation cost in \$ per container for unit distance across the arc {(i,j,δ)} that is formed in the network in the time slice δ, where $i \in O, j \in D$ and $\delta \in \varDelta$.
$w_{i,j,d}$	Capacity of arc $\{(i, j, \delta)\} \in A$ that is formed in the network, in the time slice δ, where $i \in O, j \in D$ and $\delta \in \varDelta$.
$a_{i,\delta}$	Count of empty containers available in the time slice δ, where $i \in O, j \in D$ and $\delta \in \varDelta$.
$b_{j,\delta}$	Count of trucks, empty required at pickup locations in the time slice δ, where $j \in D$ and $\delta \in \varDelta$.
Variables	
$x_{i,j,\delta} \in \mathbb{N}$	Number of trucks moving across an origin destination pair (i, j) for a time slice δ, where $i \in O, j \in D$ and $\delta \in \varDelta$.
$0 \leq x_{i,j,\delta} \leq w_{i,j,\delta}$	Bounded within the capacity of an arc

Table 2 Container movement distribution across time slices in Q1.

Type	Average
Domestic moves	1%
Export pickups	36%
Import drops	52%
Positioning of empties	11%

6 Results

6.1 Data Exploration

The hinterland management includes the full container drops and pickups, timely collection of the empty con-

Table 3 Container distribution across transport modes

Mode	Average
Barge	1%
Railways	43%
Trucks	56%

Table 4 Transport mode and Haulage

%	Local Haul	Long Haul	Short Haul
Barge	0.3	0.1	0.5
Rail	0.3	38	6.3
Truck	31	8.4	15.2

Table 5 Supply and Demand node distribution across time slices for NAM global.

Slice	Supply Nodes #	Demand Nodes #
T2	497	292
T3	555	308
T4	497	298
T5	564	308
T6	551	303
T7	552	288

tainers post the de-stuffing of the import goods and facilitating the empty containers to the geolocations where export goods are to be stuffed based on the appointment times prefixed with the customers or to predetermined storage locations. Table 2 illustrates the container movement statistics for the first quarter of NAM in 2019, which asserts that imports are far more than exports in NAM, for the data under study. The container category considered for this study is 40 feet dry containers.

In a typical week, the distribution of the container movement across the available transport modes at a zip code level, across the first quarter of 2019 is recorded in Table 3. Data exploration indicates that while trucks are the preferred mode of transport of containers for short hauls and local hauls, the long haul transportation of the containers is mainly through the railways. Trucks do contribute to the long haul (8.4%) pick-up and drop of stuffed and empty containers mainly from the geo-locations that are isolated from the well-connected transport network. Table 4 illustrates this for 2019 Q1.

In the NAM region, the number of distinct supply nodes and the number of distinct demand nodes across time slices is illustrated in Table 5, this is as expected indicating the nature of the trade in USA which is leaning towards imports. The distance matrix between the supply and demand nodes is as indicated in Fig. 4. Tables 6 and 7 illustrate the supply and demand node distribution across the identified cluster and the data considered for triangulation exercise.

Table 6 Supply and Demand node distribution across time slices in identified cluster

Slice	Supply Nodes #	Demand Nodes #
T2	52	24
T3	59	28
T4	67	36
T5	62	30
T6	53	30

Table 7 Supply Demand Node distribution for Triangulation scenarios

Slice	Supply Nodes #	Demand Nodes #
T2	58	21
T3	62	27
T4	61	28
T5	66	29

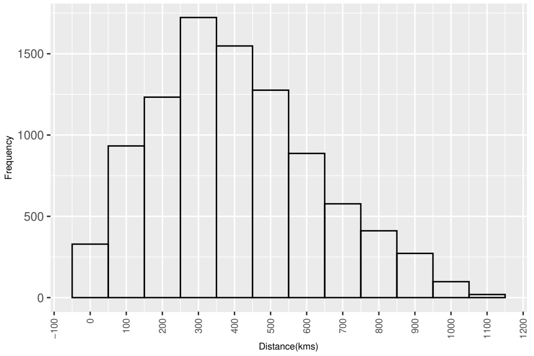


Fig. 4 Distance matrix

6.2 Numerical Analysis

This section contains the analysis of the proposed approach for weekly aggregated data from a shipping organization. We have seen that NAM region is import heavy hence has a higher number of import drops than export pickups, though state-wise clustering has shown that some states matching or mismatching this pattern locally as shown in figure Fig. 5. Since the locations that are import/export heavy are rarely geographically co-located effective placement of empty containers at strategic locations is an important business requirement. The geo-locations where the containers can be stored include rail yards which in general are well networked and can also be considered as hubs for empty containers. We specifically focus on the cluster that covers neighbouring states, states of Georgia (export heavy) and South Carolina (import heavy) on the west coast of USA to demonstrate numerical analysis of the model as the data of these states show interesting trade dynamics.

We have generated state-wise clusters for imports, exports and empty containers in the inventory for a discretized time slices δ. Let the import containers and po-

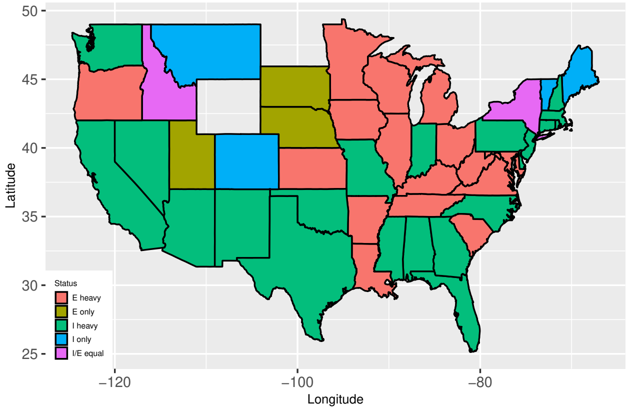


Fig. 5 Import-Export distribution across states.

sitioned empty containers, and the containers required for exports for a discretized time slice be denoted as δ be $I(\delta)$, $E(\delta)$, $P(\delta)$. For a particular δ, an assumption is made that all import containers after their respective drop are made available for export pickups in the immediate next time slice via triangulation. Further, we also assume that δ time slices are on weekly basis. Imports by triangulation are assumed to be via trucks, but the positioning is done by rail route alone. Export pick of containers can be done via rail or road.

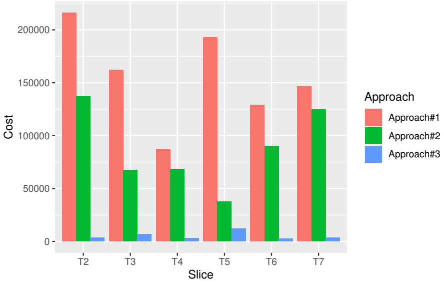
We have used the open-source mixed-integer programming solvers of Pyomo in Python for the implementation of the model [14]. For the transportation cost $c_{i,j,\delta}$ we have assumed a blanket cost of \$2 per container per km across all the arcs for generating the total cost aggregates displayed in this section. The optimization network is run in local clusters for the test instances for all the states with each around 100 nodes or less, the results of the total costs are shown in Table. 6 for few time slices for comparison. We have noticed that the MIP model was able to run smoothly in a runtime of less than a second for all the test instances. Even for the whole NAM global cluster where the node distribution is indicated in Table. 7 we have noticed a run time within a second for all the test instances. Customization of a faster heuristic based on the Successive Shortest Path algorithm [24] implemented via networkx package [13] can be used for scale-up in case nodes are in order of 10s or 100s of 1000s, as an exponential increase in nodes can cause a similar increase in the runtime of exact solvers solutions. Since all the data instances of local and global clusters for all the discrete-time slices were of the former category we are not including the heuristic exploration here.

A sensitivity analysis by source is computed for each of the cluster networks to further analyze the total cost sensitivity to the supply at the nodes. Marginal values are calculated for the network cluster to see how sensitive the total cost is with respect to the increase or decrease in the available containers at the storage locations within the cluster. If sensitivity analysis shows the marginal values as zero along with an unused available supply at corresponding nodes for a minimum cost solution, one can safely plan for decreasing the existing supply at that location. On the other hand, if the marginal value is a negative real number 'c' at the source location indicating the whole existing supply being used, a further possibility of reducing the total cost by 'c' dollars for every additional container made available at that source exists. Hence a strategic and tactic conclusion can be drawn that any excess supply available marginal value 0 nodes can be moved to these nodes with negative marginal values. In what follows, we compare the total costs for clusters by varying supply at source nodes. Three specific business strategies are demonstrated below for comparison. For all the three scenarios all the cluster parameters except the supply at the source nodes remain the same.

Approach 1: This is the basic case with the supply (import drops and empties in storage locations) and demand (export pickups) data available from the work order data. The import drops and the export pickups scheduled apriori through work orders across identified time slices for the cluster under selection and was used for the optimization process. All the import orders after the delivery were considered for reuse via triangulation for the export pickups. The available empty containers stocked within the storage locations are also considered as a source for empty containers for export pickups. For the whole cluster total supply to the network is always greater than the demand for a particular time slice, in the given data. The optimizer engine matches the nearby sources to the nearby supplies by a minimal cost assignment. This approach gives the optimal output for the given network as the parameters are fixed according to the inventory availability at respective source locations.

Approach 2: Here, the proactive planning of empty container requirement at identified storage location from the data, looking into the future booking in the required time horizon is worked on. We work on the assumption of having sufficient means to meet the required empty containers stock level, the identified stock is moved apriori to these hinterland storage locations. Based on the marginal values generated after the sensitivity analysis by source nodes for the network in Approach 1, containers are positioned such that the total cost comes further down. When the stock position at the identified strategic storage locations is planned to meet all the customer demands in the neighbouring region, the optimization approach#2, invariantly gives a much lower cost leading to a significant amount of savings, both at NAM and cluster levels as to our proposed Approach 1 as indicated in Figures 7 and 6.

Fig. 6 Trucking cost across approaches for specified time slices - cluster#1 data



Approach 3: This scenario to capture an ideal solution, where every customer demand is met, each time a commitment is made, for import drops as well as export pickups, across time slices. At this stage, a positive imbalance identifies an opportunity for up-selling to prospective customers, which can be identified apriori using a go-to-market analysis, which is not covered as a part of this research work. This in turn can help market excess containers to maximize utilization, across clusters.

Fig. 7 Trucking cost across approaches for specified time slices - NAM global cluster.

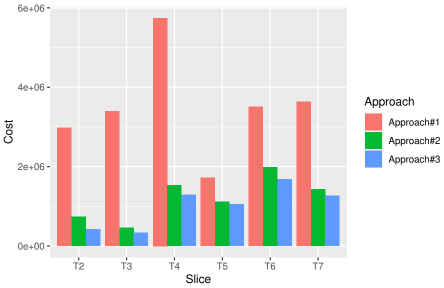


Fig. 6 and 7 illustrates the outcome of the result of the experiment of approaches #1, #2 and #3 across time slices, for identified cluster and at NAM global level. It is evident that the total costs savings are valuable, for approach 2 averaging reduction in the trucking cost is 32% compared to approach #1, while with approach #3 with good positioning to meet every demand at the demand location (happy dream) reduces the cost on an average by 91%.

7 Conclusions

We have seen that smart positioning by the proposed model for the discrete-time windows can lead to potential business savings for both pickups and delivery of import-export containers. Further, the possibility of reducing empty backhauls and smart positioning open the opportunity to reduce pollution and minimize empty truck legs, which is a step towards reducing the carbon footprint. The quantum of opportunities for these operations is significant in any standard supply chain with multimodal transports and the possible estimates of healthy savings can be used for efficient vendor negotiations during the contract phase as a business strategy.

In NAM region we have seen that the last mile of the transport by trucks and the internal network of trains are mostly owned and managed by private or third party vendors. The truck vendors are usually contracted locally by the destination service teams of the supply chain managers or 4PL/3PL freight forwarders on an ad hoc manner while at times customer-preferred or carrier-preferred are choice decisions as well. The railways work independently upon the request to manage the supply chain. All of these are operated by private parties at a global level in NAM, and contracts are usually in place with the shipping organization with its rail-related supply chain management.

The inland container movements (from the seaports to the customer store door and vice versa) have short hauls (cover the last mile drop or pickup of containers) and long hauls (movements across locations that are not connected by railways). The operational planning including the empty container positioning is an important business requirement for making the empty containers available for reuse and for evacuation.

One of the main challenges seen in NAM business area is the lack of visibility of inland movements of the containers, both for import drops and export pickups. Visibility is enabled if the container or the transport vehicle is RFID tracked. Container tracking is desired and opted for when refrigerated containers are in transit and mandatory when dangerous goods or pharmaceuticals are loaded in the containers.

In most of the cases, until gate-out-full container returns to the warehouse/container yard gate-in-empty or full, the geolocations of the container are estimated and not tracked real-time. This poses a challenge when the inland distributions are far spread and silo clusters that are not well networked into the transit routes exists.

Further, to make it more complex there are various external actors with different stakes in the dynamics of the inland network. Shipping lines and freight forwarders use the network as a means to provide services to their customers while competing with other shipping lines. Though most of the commercial ports finance their operations through the profit they make, there are inland ports that operate on subsidized government initiatives with an aim to enhance the local economy.

The port of Savannah under Georgia port authority is an example. For the study demonstrated in this paper, we considered two neighbouring states on the west coast of USA for demonstration purposes: in the data under study, export-heavy Georgia and import-heavy South Carolina both showing interesting trade dynamics. Prominent ports, the Port of Savannah, known as the NAM gateway and Brunswick together with inland terminals in Chatsworth, Bainbridge and Columbus form Georgia's gateway to the world. The Port of Charleston and Port of Georgetown and inland ports of Geer and Dillion plays a similar role for South Carolina [23].

Analysis of the proposed model focuses mainly on the last mile of the supply chain in these two states focussing on empty positioning and import empty container triangulations for the export picks ups. Some of the future interesting explorations would be the extensions of the model for more detailed analysis on actual operational data, vendor details, time-tables/schedules of third-party logistics involved, actual appointment times, confirmed bookings for the future along with the possibility of upselling the unused containers instead of direct evacuation.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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