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Freight Transportation Service Provider Collaboration: Benefits and Insights

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***Abstract* — Truck-based freight transportation in the United States is expected to remain an integral part of the economy for the foreseeable future. Despite its continued importance, the industry remains fragmented and economically, socially, and environmentally unsustainable. The focus of this research is exploring opportunities to reduce costs and increase sustainability through collaboration among transportation service providers (TSPs). The objective is to explore freight routing and consolidation decisions for collaborating transportation service providers, introduce the transportation service provider collaboration problem (TSP-CP), and evaluate the potential benefits of TSP collaboration using industry representative data sets. The results provide new insights on the benefits of collaboration as well as the effects of the type and size of the TSP on the expected benefits derived from collaboration.**

Keywords — freight transportation, transportation service provider, collaboration

I. INTRODUCTION

Truck-based freight transporters carry approximately 72% of all freight tonnage in the United States, which amounts to approximately 10.93 billion tons of freight and 175 billion miles annually [1]. Freight transportation by truck includes two primary modes: full truckload (FTL) and less-than-truckload (LTL), with FTL representing 56% of the freight transportation service provider industry in the U.S. and LTL representing an additional 29% [2]. The remaining 15% includes a combination of different specialty carriers that are not considered in this research. Despite its size and importance, the truck transportation industry continues to struggle with fulfilling transportation requests in an efficient and sustainable manner. In addition, the current state of the trucking industry is not sustainable as environmental emissions are high, trailers are under-utilized (~43% utilization on average), and driver turnover is substantial, especially for truckload drivers.

The purpose of this research is to evaluate opportunities to reduce costs and increase sustainability through collaboration among transportation service providers (TSPs). In order to fully realize the benefits of collaboration between FTL and LTL carriers, the limitations of current routing and consolidation decisions must be overcome. The objectives of this research include the following:

- exploring freight routing and consolidation decisions for collaborating TSPs;
- introducing the transportation service provider collaboration problem (TSP-CP); and
- evaluating the potential benefits of TSP collaboration using industry representative data sets.

In the following sections, additional background is provided on the typical operations of FTL and LTL carriers. The transportation service provider collaboration problem (TSP-CP) is described along with a brief summary of the solution approach. Finally, the TSP-CP is solved using data from 67 TSPs, and the benefits of collaboration are analyzed and described.

II. BACKGROUND AND MOTIVATION

A. Full Truckload Operations

Full truckload (FTL) carriers tend to handle large shipments (often 10,000 lbs or more) by delivering transportation requests (loads) directly from origin to destination. In order to deliver directly from origin to destination, an FTL carrier requires that the entire delivery resource capacity is purchased when requesting a full truckload shipment. This enables FTL carriers to deliver transportation requests directly using a single delivery resource without any intermediate consolidation. These practices support fast delivery times and limits the number of times that a transportation request is handled.

This approach, however, generally results in lower delivery resource capacity utilization and shipments often require delivery over a great distance. FTL carriers tend to operate over a large geographic region, rendering it difficult to build routes that allow drivers to remain close to their domicile. Due to this, an FTL driver can be away from their home for extended periods of time. As such, the FTL industry is plagued by problems with driver shortages, driver turnover, and shipping less than full trucks over long distances.

B. *Less-than-truckload Operations*

Less-than-truckload (LTL) carriers tend to handle smaller shipments and consolidate multiple transportation requests onto a single delivery resource at a consolidation hub. An LTL network consists of two different types of locations: end-line terminals and break-bulk terminals. An end-line terminal serves as an origin or a destination for freight shipments, while a break-bulk terminal is where consolidation happens. The break-bulk terminals consolidate shipments from end-line terminals and other break-bulk terminals to build full or nearly full delivery resources. When enough volume has been accumulated, the delivery resources then travel to the next break-bulk terminal or a destination terminal. Once shipments reach the next break-bulk terminal they either remain on the current delivery resource heading to another break-bulk terminal or they are moved to another delivery resource heading for their destination end-line terminal or to another break-bulk terminal where this process is repeated.

In order to handle the complexity of allowing both intermediate consolidation and routing decisions, LTL carriers often use predetermined load plans that stipulate the sequence of break-bulk terminals that a shipment will travel through given the origin and destination terminals. The load plan supports quick and consistent decisions for each transportation request and delivery resource, but can result in sub-optimal freight consolidation and routing decisions. Additional delivery time is also required in order to consolidate enough LTL shipments for efficient delivery.

C. *Importance of Effective Operations*

Maintaining efficient and sustainable operations through freight consolidation and routing is essential for enabling transportation service providers to compete in a largely segmented industry. The current practices highlighted by both segments of the industry create many of the problems that the industry is facing today. Industry estimates suggest that approximately 25% of all miles are traveled with an empty delivery resource, and the remaining 75% of miles are traveled at only 56.8% full on average. This results in delivery resources travelling the road at only 42.6% full on average [7].

In addition to this inefficiency, truck transportation is also environmentally and socially unsustainable. Truck transportation was responsible for approximately 8.8% of total U.S. greenhouse gas emissions in 2022 [3]. The industry is also plagued with driver shortages resulting from high turnover rates and extended time away for drivers. Currently, the industry estimates a shortage of nearly 78,000 drivers [4], and long-haul truck drivers have a turnover rate of more than 70% [5]. Industry fragmentation also tends to exacerbate the problems the industry is already facing. In 2021, approximately a million trucking companies were on record in the U.S., with nearly 90% of those containing fewer than 6 trucks [6].

With the importance of truck transportation for the U.S. and global economy, new approaches must be leveraged to enable a more economically, socially, and environmentally sustainable industry moving forward. One potential solution is collaboration among TSPs, where they share volume, resources, and facilities to reduce costs and increase sustainability. In a collaborative scenario, the loads of two or more TSPs are delivered using the combined set of facilities and delivery resources. To evaluate the potential benefits of this collaboration, we develop the transportation service provider collaboration problem.

III. PROBLEM DESCRIPTIONI

The transportation service provider collaboration problem (TSP-CP) provides optimal freight routing and consolidation decisions for a set of collaborating TSPs. To overcome the limitations of current practices, the TSP-CP combines the loads, facilities and delivery resources of multiple TSPs. The transportation service provider collaboration problem is briefly summarized in Fig 1.

The TSP-CP is modeled as a variant of the pickup and delivery problem with time windows and transshipment (PDPTWT) by Roesch [8]. In this model, the combined set of transportation requests are serviced using the interconnected

Given

- Transportation network
  - nodes and arcs
- Set of discrete time periods
- Set of delivery resources (trailers)
- Set of loads

Determine

- Routes for loads
- Routes for containers
- Assignment of loads to containers

Objectives

- Minimize the following:
  - cost of container routes
  - cost to handle and hold loads

Constraints

- All loads are delivered
- Time windows are considered
- Container restrictions are met
  - start and end at pre-specified nodes
  - capacity is never exceeded
- Node restrictions are met
  - Loads are only transferred and held at transshipment nodes

Fig 1. Transportation service provider collaboration problem summary.

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network and pooled delivery resources created by the collaborating TSPs. The model prescribes the optimal routing decisions for the collaborating carriers. Additionally, the potential for freight consolidation at intermediate locations enables the transition of transportation requests between delivery resources.

Specifically, the TSP-CP is modeled as a time-expanded pickup and delivery problem with time windows and transfers (PDPTWT-t), which provides optimal consolidation and routing solutions for large scale transportation networks [8]. In a time-expanded network, a node represents both a physical location and a time period, as illustrated in Figure 2. The objective of the PDPTWT-t is to deliver all transportation requests while minimizing the transportation costs for delivery resources and the handling and holding costs of transportation requests.

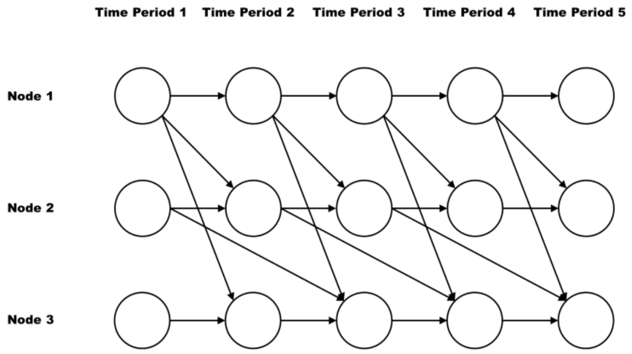

Fig 2. Time-expanded representation of the transportation network.

Given a set of transportation requests, a set of delivery resources, and a transportation network consisting of nodes and arcs, the PDPTWT-t simultaneously determines the routes of transportation requests, the routes of delivery resources, and the assignment of transportation requests to delivery resources. The PDPTWT-t provides additional flexibility over the traditional pickup and delivery problem by allowing transportation requests to be transferred between delivery resources at transshipment nodes. These transfers involve physically moving a transportation request from one delivery resource to another in order to obtain better resource utilization and lower overall costs. Although, each transportation request must be carried by a delivery resource, having independent routes for the transportation requests and the delivery resources allows decoupling the transportation requests from the delivery resources to achieve flexibility. This decoupling is possible through separate variables that represent the movements of loads and the movements of containers.

For this study, the operational decisions for carriers are assumed to be coordinated centrally by a single entity that has access to all required information about freight, delivery resources, and facilities. This assumption of centralized control provides best case results when assessing the potential benefits of collaboration. In the future, additional research is warranted on the ideal control mechanisms for collaboration among TSPs.

IV. SOLUTION APPROACH AND ANALYSES

To address the TSP-CP problem while considering these characteristics, a discrete time adaptive large neighborhood search (ALNS) heuristic was developed and applied using industry data [8]. The heuristic was implemented using the Java programming through the Eclipse IDE. The results were generated using a workstation using an Intel E5-2620 2.4 GHz processor and 32 GB of RAM.

The industry representative data sets were derived from actual transportation service provider data, which was provided by a freight pooling company that specializes in coordinating horizontal collaborative partnerships. The data captured annual freight movements from 16 FTL carriers and 42 LTL carriers. Daily loads between origin and destination locations were extracted from the data. Load sizes were determined based on the volume traveling between the origin and destination locations in the industry data. The load sizes were converted to a fraction of a container, and all container capacities were assumed to be one.

Using the 16 FTL carriers and the 42 LTL carriers, 67 collaborative partnerships were created for evaluation. Collaborative partnerships of up to four carriers were investigated. The 67 collaborative partnerships included 35 two TSP partnerships (2-TSP), 17 three TSP partnerships (3-TSP), and 15 four TSP partnerships (4-TSP). Table 2 details the number and average size of the collaborative partnerships.

V. BENEFITS OF COLLABORATION

Using the discrete time ALNS heuristic, these partnerships of 2 carriers, 3 carriers, and 4 carriers are evaluated based on carrier type, size, and geographic location. The primary performance measures evaluated include the following:

- distance traveled
- empty miles
- weighted full miles, and
- container usage.

TABLE 1. INDUSTRY REPRESENTATIVE DATA SETS: COLLABORATIVE PARTNER OVERVIEW

Name	Partners	Count	Avg Loads	Avg Nodes	Avg Containers
2-TSP	2	35	24	28	19
3-TSP	3	17	31	37	26
4-TSP	4	15	32	39	30

Benefits were determined by calculating the percentage difference between these performance measures when the carriers operate independently and the values found when the carriers in a partnership collaborated. Figure 2 summarizes the percent differences in miles travelled, empty miles, weighted full miles, and containers that were found between the collaborative scenario as compared to the non-collaborative scenario. The decrease in miles travelled contributes directly to a reduction in environmental emissions as well.

The results suggest that as more partners are involved in the collaboration, the benefits increase. As shown, the 2-TSP partnerships provided a 12% decrease in total miles, a 24% decrease in empty miles, and a 14% increase in the percentage of weighted fill miles, with 10% fewer containers on average. The 4-TSP partnerships provided an average 22% reduction in miles, a 44% reduction in empty miles, a 29% increase in weighted full miles, and 18% fewer containers.

In addition to quantifying the benefits of collaboration, we also explored how the benefits were distributed across the type of carrier (FTL or LTL). Individual carrier benefits depend on partnership characteristics as follows:

- With 2 ‑ TSP partnerships
  - FTL carriers tend to benefit the most from collaboration.
- With 3 ‑ TSP partnerships
  - FTL and LTL carriers receive approximately the same benefit.
- With 4 ‑ TSP partnerships
  - LTL carriers tend to benefit the most from collaboration
  - FTL carriers still benefit on all four performance metrics.

Across all partnerships, collaboration between only FTL carriers provided the most benefit while the collaboration between only LTL carriers provided the least benefit.

VI. Conclusions and Future Research

Based on the collaborative partnerships, the results suggest the following: FTL carrier only partnerships received the most overall benefit on average; LTL carrier only partnerships received the least overall benefit on average; and small carriers benefitted substantially more from collaboration. Moving forward, additional research is required on the TSP-CP and on horizontal collaboration in transportation, in general. Two primary areas of interest include allocating the benefits of collaboration among the carriers and consolidation and route planning with decentralized control.

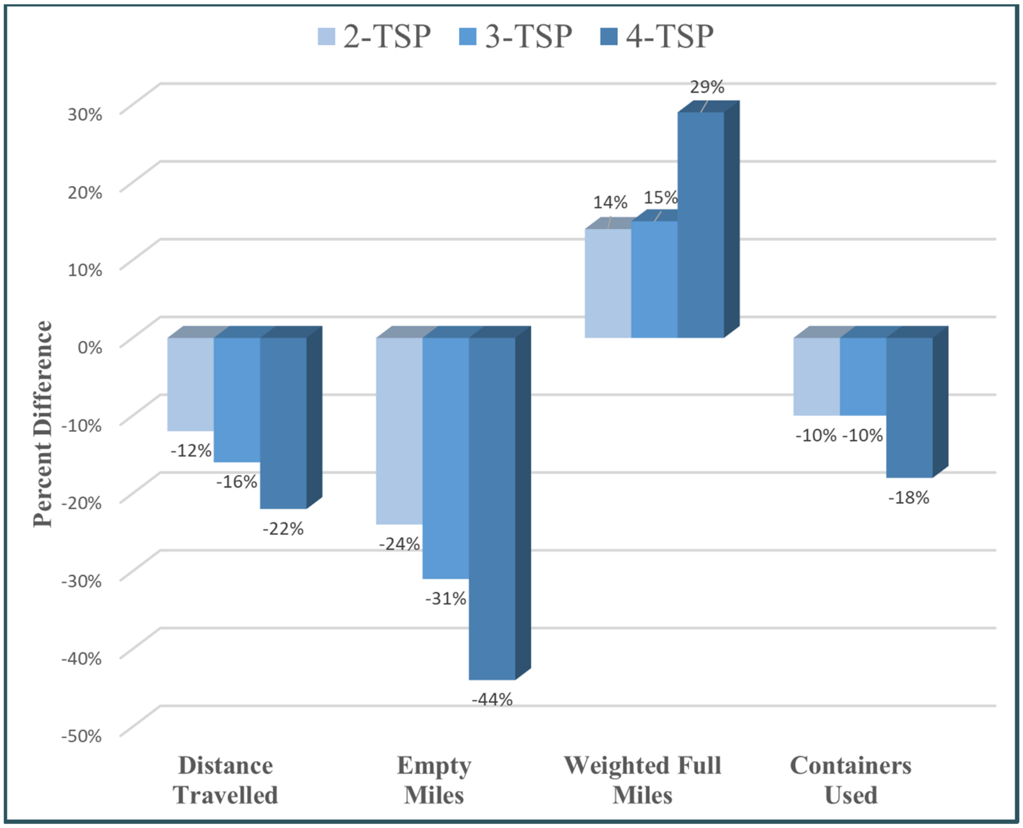

Fig 3. Improvements in performance measures as collaboration increases.

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