

Development of Trustworthy Intermodal Traffic Measurement

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A Report Submitted to the

National Center for Intermodal Transportation: A partnership between the
University of Denver and Mississippi State University

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PREFACE

The work described here was funded by the National Center for Intermodal Transportation (NCIT), a United States Department of Transportation research center operated by the University of Denver and Mississippi State University (MSU). The authors would like to thank Mr. Ted Prince for his effort in initiating the project and providing technical guidance and support throughout the research process.

ABSTRACT

As the result of increased level of highway congestion and rapid growth in freight traffic, intermodal freight transportation has become increasingly more important to a sustainable surface transportation system in the U.S. To meet the requirements of policy making, planning and operation of freight transportation, credible freight intermodal measurement is essential. However, reliable and true intermodal freight traffic measure is not currently available.

This study looks into the intermodal aspects of rail truck operation and is intended to shed some light on how the current measures are compiled, whether they are reliable, and if there are improvements that can be made. By investigating proprietary data provided by transportation providers, the potential shortcomings of current reporting and compilation practices are discussed, and procedures to obtain more reliable measures are suggested. The study particularly pointed out the fact that the number of transactions involved in the intermodal trips could have directly resulted in inaccuracy in intermodal flow measurement and suggested a possible counter measure of establishing a unique trip identification number.

This study is an attempt to better understand the current problems and to propose improvements. Further work is needed for the study of current reporting practices, for detailed plans of new data collection and reporting procedures, and for implementation of the developed plans.

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1. INTRODUCTION

Intermodal freight transportation has been attracting increasingly more attention in recent years, especially since the enactment of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991^[1]. The emphasis of the importance of intermodal freight transportation is a logical step towards improving mobility and efficiency of transportation in the face of the ever-increasing level of congestion on the nation's highways. According to an October 17, 2002 USA Today article, nationally, travel on interstates and other federal highways increased 38% from 1990 to 2000, while over the same period, the total number of freeway lane miles grew just 8% based on Federal Highway Administration (FHWA) data. Travel on highway networks has outgrown capacity expansion, and the result is a more serious level of congestion. According to a recent FHWA report "Traffic Congestion and Reliability: Linking Solutions to Problems"^[2], sixty-seven percent of the peak-period highway travel in 2001 is congested compared to 33 percent in 1982. Travelers in 75 urban areas spent 3.5 billion hours stuck in traffic in 2001, up from 0.72 billion in 1982. Fifty-nine percent of the major road system is congested during peak hours compared to 34 percent in 1982.

Freight transportation demand has also experienced a fast pace of growth. It is expected that freight traffic in the U.S. is to grow substantially over the next 20 years. Figure 1 shows the data from USDOT's office of operations on projected freight shipments. It shows that domestic and international freight volumes are to increase by 67 percent and 85 percent, respectively, between 1998 and 2020.^[3]

U.S. Freight Shipments by Tons (billions)

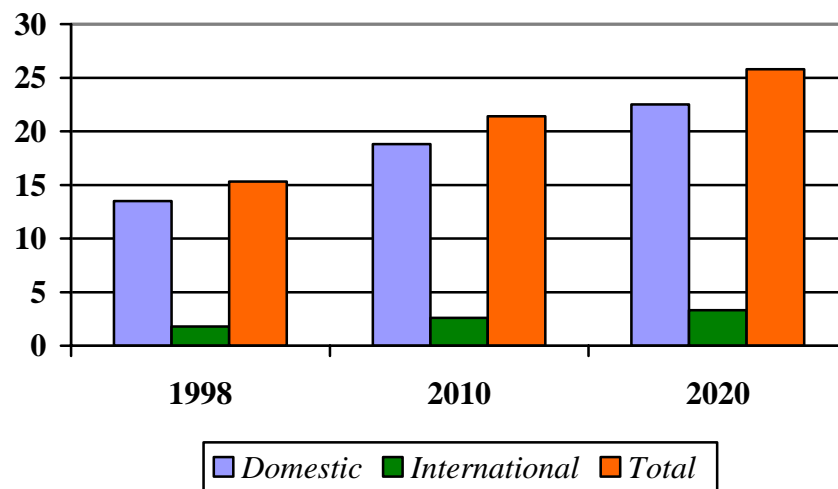


Figure 1. Projected U.S. Freight Shipments

The growth in freight traffic is being driven by economic and population growth, and fueled by the globalization of trade and just-in-time manufacturing. The U.S.–Asian Pacific trade and North American Trade are growing at a rapid pace, and the international trade will continue to bring in high growth of truck traffic on certain highway routes as identified by the Latin America Trade and Transportation Study (LATTTS) [4]. The increase of freight traffic leads to more congestion on rural Interstate highways, causing congestion to spread outside of metropolitan areas.

Rail is a very important mode for freight transportation. It is commonly agreed upon that rail provides advantages in transporting bulk commodities over long distances. With many recent improvements to the rail system, freight trains are now much faster and can offer timings and service reliability that can match freight trucking. Considering the congestion cost on highways and drastically increased fuel cost, rail freight can also be economically advantageous for many other commodities that may not be traditionally carried by rail. Capacity is another issue of consideration. While highway capacities are being approached or exceeded, rail system is still

somewhat underutilized. In addition, the rail freight industry has been steadily increasing average train payload, and also using heavier and longer trains that translates to more capacity.

In the U.S., about three-fifths of the intercity tons of goods are handled by truck and about one-fourth handled by railroad [5]. Certainly rail freight may not always provide door-to-door service and needs to be complemented by trucking, commonly at both ends of the trip. This makes trucking and rail a very important combination of intermodal transportation for freights.

According to the volumes of goods and their characteristics, the main modes of intermodal freight transportation are between railroad and truck, which combine the efficiency of railroad transportation with the flexibility of truck mode.

In recent years, many research efforts were made studying different aspects of intermodal freight transportation. Most of the research work is in the areas of intermodal network design and modeling, and intermodal operations. Location theory was applied to deal with several spatial aspects associated with transportation, especially with network design problems [6]. Hub network design, formulated by O'Kelly (1986) was applied to intermodal terminals, where the hub was defined as a nodal point for processing freight flows. However, one important disadvantage of this formulation is the great number of decision variables for large applications. Later, another formulation for intermodal modeling was presented based on multicommodity fixed-charge network design. Pierre Arnold et al. developed intermodal transportation location formulations in 2003. In the model, several terminals can be solved simultaneously with a criterion of minimization of the total transportation costs. While analyzing intermodal freight transport network, E. D. Kreuzberger presented a way of bundling flows (these flows often have different origins and/or destinations) and realizing short load unit exchange times at nodes [7]. Moreover, TERMINET, a terminal network model, was developed [8] to determine the locations and capacities of road and rail terminals where transshipment happens between trains and road vehicles. In this paper, it is found that long distance (700km) intermodal transport is to be cheaper than monomodal road transport and medium distance (500 km) transport has similar transport costs. Although many efforts have been made to develop the efficiency of intermodal

operation, some obstacles, such as lack of adequate infrastructure, congestion, financial limitation, still remain. When considering intermodal operation, time [⁹, ¹⁰] and cost are most important factors. Alexandra M. Newman, focusing on rail transportation of intermodal containers and aiming to minimize operating costs while meeting on time delivery requirements, formulated the problem as an integer programming problem and developed a novel decomposition procedure to find near-optimal solutions^[11]. The operational selection of intermodal ramps is another key aspect that affects the efficiency of rail-truck transportation. G. Don Taylor et al. examined two alternatives (Intermodal delivery methods) of ramp selection used to reduce empty and circuitous miles incurred during intermodal drayage movements [¹²]. Ali Haghani developed a mathematical model (a mixed-integer linear programming problem) for developing plans for loading containers^[13]. Powell et al. proposed a dynamic model for optimizing flows of flatcars, and the problem is formulated as a logistics queuing network [¹⁴].

In order to reap the most benefits of intermodal freight transportation, federal and state governments and private transportation industry need to work together to make policies, planning for improvements of intermodal network, and facilitate mode changes and operations. One of the key issues involved in any process of policy, planning and operations is the measurement of intermodal flow. However, this is an area that has not seen much research work done, and reliable statistics and accurate measurement of intermodal flow have not been developed. This project is intended to investigate proprietary intermodal transportation data to assess the nature of freight movements of various types, and to look deep into the intermodal operations of freight transportation. Based on accurate representation of intermodal trips, a prototype methodology will be developed that can potentially be implemented at larger scale and become a standard method of compiling intermodal traffic data.

2. INTERMODAL DATA

Data sources used for intermodal freight transportation include information about freight flows by mode, by commodity, and by other characteristics. In the report “Intermodal Freight Transportation” [5], data sources are divided into primary (specific data activities) and secondary (existing or ongoing data collection efforts being performed) sources according to data collection responsibilities. The most common techniques for gathering primary transportation data are mail/telephone surveys, direct interviews, and traffic monitoring. Secondary data sources include existing databases and compilation of data that provide useful information in evaluating intermodal transportation.

2.1 Intermodal Transportation Databases

The following are the secondary data sources useful for intermodal (rail and truck only) freight transportation practices:

Carload Waybill Sample

The annual Carload Waybill Sample [¹⁵] is developed by the Association of American Railroads (AAR) under contract with the Surface Transportation Board (STB) (previously the *Interstate Commerce Commission*). The annual database captures detailed information on total rail traffic, commodities, revenues, origin-destination flows, and routing information for U.S. railroad shipments. Public Use File is developed from Master file and is available at the end of July each year. The sample provides information on the commodity carried, the number of cars in the shipment, the revenues charged on the shipment, the railroads involved in the shipment, origins and destinations of the shipment, and other various data.

Data collection Procedure

Carload waybills are collected by the AAR from railroads that move at least 4,500 carloads per year over the last 3 years or 5% or more of any state’s total traffic. The actual waybills filed by railroads are sampled based on the number of carloads on the waybill. The carload waybill

sample for each year contains over 350,000 records. The data are collected by the following procedure:

- 1) The carload waybills are collected by the AAR;
- 2) Freight railway companies satisfying minimum size criteria of at least 4,500 carload shipments in the past 3 years or more than 5% of the state's traffic have to submit carload waybill.
- 3) The carload waybills are submitted to the AAR in two formats: Hard Copy Version (Manual System) and Machine Readable Input (MRI-Computerized System).
- 4) A stratified sample is selected from these waybill records by the AAR to compile the *Carload Waybill Sample* database.
- 5) The traffic and revenue values collected for the sample are then converted to annual values by using the following expansion factor:

Exact Expansion Factor = Population count / Sample count

Limitations

- Due to the minimum threshold level (minimum number of carloads) considered in the reporting of carload waybills, some Class II and Class III railroads are often not covered in the *Carload Waybill Sample*.
- The expanded factor values obtained might not be accurate.
- In same case, the *Carload Waybill Sample* does not report BEA regions of origins and destinations for commodity shipments

Freight Commodity Statistics (FCS)

The Freight Commodity Statistics (FCS) database is developed by the Association of American Railroads (AAR) on a quarterly and annual basis. The FCS database contains detailed shipment statistics by up to 5-digit Standard Transportation Commodity Codes (STCC) by Class I railroads (*railroads with minimum operating revenue of \$261.9 million*) in terms of the number of carloads, shipment tonnage, and the gross freight revenue. The main

limitation of FCS is that this database does not report commodity shipment for Class II and Class III railroads, although these railroads only account for approximately 9% of the total railroad shipment revenue.

Data collection Procedure

- 1) Class I railroads report their quarterly and annual commodity statistics to the STB, a requirement since 1964.
- 2) The AAR collects these commodity statistics and compiles the *Freight Commodity Statistics* database.
- 3) The commodity statistics for the U.S. are computed by summing the quarterly and annual carloads, tonnage, and revenue data for all the Class I.
- 4) The commodity statistics for the Eastern and Western districts are computed by adding the quarterly and annual carloads, tonnage, and revenue data for the railroads having their corporate headquarters located in the Eastern and Western districts, respectively.

Data Sources of Short-line and Regional Railroads

To estimate the proportion of rail carloads of various commodities that short-line railroads (Class II and Class III) handled at some point between their origin and destination, two primary sources of data are used. These data sources include the Association of American Railroad's (AAR's) Profiles of U.S. Railroads database, and the American Short Line and Regional Railroad Association's Annual Data Profile. When used alone, each of the two primary data sources have potential deficiencies for making an assessment of short-line participation in rail carloads. However, when used in conjunction with one another, the data sources complement each other to provide a reasonable assessment of short-line carloads.

The ADP is an annual data compilation of financial and operating data for the short-line and regional railroad industry (1993-1996, 1998-1999). Data are collected from a sample of local, regional, and switching & terminal (S&T) railroads through a detailed survey. Responding

railroads report the number of carloads originated and terminated, originated and forwarded, received and forwarded, and received and terminated, by commodity.

One complementary data source to the ADP is the AAR's Profiles of U.S. Railroads database. The AAR's Profiles of U.S. Railroads (Profiles) database is a yearly compilation of carloads, miles of road, states served, top three commodities of carloads hauled and percentages of each, and various other data items for every railroad in the U.S.

Because the railroads are asked to report actual carloads of each type rather than percentages, it is believed that data on carloads of various commodities are more accurate than similar data from other sources. However, because the ADP only captures a sample of all the local, regional, and S&T railroads in the U.S., it cannot be used as a sole source for estimating the number of commodity carloads by short line and regional railroads.

Commodity Flow Survey

The Commodity Flow Survey (CFS) [¹⁶] is conducted as part of the Economic Census by the U.S. Census Bureau in partnership with the Bureau of Transportation Statistics of the U.S. Department of Transportation. This survey produces data on the movement of goods in the United States. The data from the CFS are used by public policy analysts and for the purpose of transportation planning and decision-making and to assess the demand for transportation facilities and services, energy use, and safety risk and environmental concerns.

The 2002 CFS consists of a sample of 50,000 establishments chosen based on geographic location and industry. Each establishment selected into the CFS sample is mailed a questionnaire for each of its four reporting weeks. For the CFS each sampled establishment was asked to report on a sample of individual shipments during a one week period in each calendar quarter.

Different data sources that can be used for a freight flow study have widely varied degrees of coverage, accuracy, aggregation and completeness. The commodity flow data is directly related to freight flow analysis, which includes data such as the type of commodity, the origin, the destination, the value, the weight, and the ton-miles of the shipments. These data are usually

aggregated at the state level, Bureau of Economics Analysis (BEA) Zones, or National Transportation Analysis Regions.

The commodity data are presented at the state level and grouped by the two-digit Standard Classification of Transported Goods (SCTG) code. It contains commodity flows by tons, value, and ton-miles by commodity on different modes for all states. The CFS data contains data on shipments by domestic establishments in manufacturing, wholesaling, mining, and other industries. The database contains the mode information for all the products. The modes discussed include: all modes, single modes, multiple modes, and other unknown modes. In single mode, truck (for hire truck, private truck), rail, water (shallow draft, great lakes, deep draft), air (includes truck and air), and pipeline modes are included. In multiple modes, parcel-US Postal Service or Courier, truck and rail, truck and water, rail and water, and other multiple modes are included in the database.

As a public domain data source, CFS database has drawn attention in freight transportation planning studies. Many states, such as the State of Virginia [¹⁷, ¹⁸], have used the database to obtain the four components of the commodity flow (Interior-Interior, Exterior-Interior, Interior-Exterior, and Exterior-Exterior)

Reebie Associates TRANSEARCH Database

TRANSEARCH[] draws from a wide variety of data sources covering commodity volume and modal flow, including a proprietary motor carrier traffic sample, the Bureau of Transportation Statistics (BTS) Commodity Flow Survey (CFS), and the Surface Transportation Board (STB)'s Railroad Waybill Sample. The TRANSEARCH database contains freight movements by rail, water, air, and truck from manufacturing plants, truck movements of coal, and inland truck movements of imports. The data do not include shipments by pipeline, mail or small package shipments, and secondary truck shipments involving warehouses.

Truck Inventory and Use Survey (TIUS)

Truck Inventory and Use Survey (TIUS)^[19] is a vehicle-based survey of truck activity conducted by the Census as part of the quinquennial Census of Transportation. Data in VIUS are collected using a mail-out/mail-back survey of selected trucks. Stratified random samples of registered trucks are selected from all states. This database contains information on the physical characteristics such as date of purchase, empty weight, average and maximum loaded weight, number of axles, overall length, type of engine, and body type. It also contains operational data such as the prominent type of use, lease characteristics, operator classification, base of operation, gas mileage, annual and lifetime miles driven, weeks operated, and commodities hauled by type.

2.2 Limitation of the Current Intermodal Data

Currently, most of the freight flow databases, such as those mentioned in the previous section, do not have an intermodal focus. When included, the information of the intermodal flow in those databases is not detailed and often inaccurate due to a number of reasons:

- The measurement of intermodal volume is effectively precluded by modal focus, carrier handoffs and product intermediation.
- Individual carriers can report their volume to industry aggregations, however, there is no assurance that a single, through shipment is not reported more than once.
- Some carriers may count empty repositioning as a revenue load.
- Due to transportation outsourcing, intermediation may result in an intact load being handled by more than one “carrier” – all of whom count the load as a unit of volume.
- Because of logistical management, loads may be disaggregated and reconsolidated between point of origin and ultimate destination.
- Existing transportation network analysis is more art than science, and could have contributed to inaccurate statistics on the amount of travel.

All of these issues have contributed to unreliable intermodal flow statistics, and uniform measurement is clearly lacking. A study of developing trustworthy intermodal traffic

measurement that overcomes many of the aforementioned drawbacks is thus important, and will contribute significantly to intermodal transportation research.

3. RESEARCH APPROACH

3.1 Research Objectives

The main scope of this research is to conduct a feasibility study of compiling a truly intermodal traffic flow assessment. Conducting intermodal traffic data collection and compiling traffic flow measure is a very involving and challenging task, and conducting large scale data collection is beyond the scope of this study. Instead, this study will utilize proprietary data from a small number of transportation providers. The study will try to reveal from the data how the intermodal freight flow measurement is currently presented and if it is misrepresented, and by how much, and to demonstrate how the flow should be quantified in a more credible way. In addition, by investigating the proprietary data, the research team intends to identify factors that have contributed to inaccurate intermodal statistics and to develop a credible methodology to quantify intermodal traffic.

3.2 Data Acquisition

With the help of Mr. Ted Prince of IONA, the Intermodal Association of North America, a series of conference calls were arranged between the transportation providers and the project team members. During those conference calls, the intermodal freight transportation operation and data recording and compiling practices were discussed, and requests for flow data were made. Three transportation providers that are represented on the board of ITI (the Intermodal Transportation Institute at University of Denver), partners with Mississippi State University in NCIT, the National Center for Intermodal Transportation, agreed to provide the proprietary data for this study.

One of the companies is a leading intermodal marketing company that provides comprehensive intermodal, truckload, and logistics services. The second company operates one of the largest railroad networks in North America, and offers intermodal services and industry solutions for shippers, carriers, and receivers. The third company is one of the nation's leading truck load

carriers and also provides intermodal solutions that link major rail and truckload carriers in a joint marketing environment. The selected companies are very representative of the major players of the truck-rail intermodal operations in the United States and cover both asset-based model and non asset-based model of operation.

3.3 Data Description

The provided data includes top 100 OD (origin-destination) pairs of intermodal traffic in 2002 of the respective companies based on number of carloads. Each entry of data for an O-D pair includes the following information:

- Origin city and state
- Origin rail ramp
- Destination city and state
- Destination rail ramp
- Number of carloads
- Carriers involved

The data sets do not include more sensitive price information. Data entries were assembled from companies' own databases so that they could deliver the data file to the project team in a uniform format. Entries that are apparently erroneous were removed from the data files and were not used for the subsequent analysis.

3.4 Data preparation

After datasets were received, analysis was performed to extract information related to the operation of intermodal operations. Specifically, the following categories of information were obtained from a consolidated data file that contains the data of top 100 OD pairs of intermodal (rail and trucking) traffic of all three companies:

1. Distance-related information

This category of resulting data items includes:

- Distance from origin of the load to the origin rail ramp. This distance is typically covered by trucking, and if the origin of the load is in the same city where the ramp is located, a distance of 0 is assigned.
- Distance from the destination rail ramp to the destination city. This distance is also typically covered by trucking, and if the destination of the load is in the same city where the destination ramp is located, a distance of 0 is assigned.
- Door-to-door distance. This is the highway distance (if the load were transported via trucks only).
- Ramp-to-ramp distance. This is the distance covered via rail mode.

The highway distances, origin to origin ramp, destination ramp to destination, and door to door, were calculated via mapping and routing software packages. The ramp to ramp rail distances were determined using a specialized software package PC*Miler|Rail.

PC*Miler|RAIL is developed by ALK Technologies, Inc. It is a leading North American rail routing, mileage and mapping software product for shippers, railroads, rail car lessors, rail car mileage auditors, and logistics companies. It provides point-to-point rail routing and mileage information for the North American rail network. Its industry leading routing network enables users to access 215,000 miles of rail line, over 70,000 freight stations, and detailed mileage for over 650 rail carriers.

Many of the rail trips are carried by more than one rail carrier due to ownerships of different rail lines. The actual routings of those trips were determined by the carriers and PC*|Rail software was used to obtain the rail mileages.

2. Operation (carrier) information

Carrier information sometimes is specifically given in the original dataset, and sometimes it is implied as companies typically use their partner carriers to complement their own rail lines. We specifically looked into the issue of carrier changes of the intermodal trips as it presents the

potential of duplicated reporting or inaccurate reporting, such as one segment of the trip being reported as a separate independent trip.

4. FLOW DATA ANALYSIS

Detailed statistical analysis was performed with the data set in an attempt to better understand intermodal flow and to seek clues of better flow measurements. The findings and results are documented in this section.

4.1 Segment Distance distribution

Each intermodal trip has segments that may be carried by different carriers and/or by different modes. We particularly looked into the segments that are carried by truck, namely from origin city to origin rail ramp, and from destination rail ramp to destination city, and the segments carried by rail, the portion from the origin ramp to the destination ramp and the distribution of segment distances.

Top 100 OD Pairs

With data of the consolidated 100 OD pairs from all companies, it was found that the mean origin to origin ramp distance is 82.33 miles, the mean ramp to ramp distance is 1947 miles, and the mean destination ramp to destination distance is 66.58 miles. The majority of OD pairs have origin to origin ramp distance of less than 50 miles, destination ramp to destination distance of less than 50 miles, and the ramp to ramp distances for the top 100 OD pairs are between 600 miles and 3500 miles. The details are presented in Table 1. Figures 2 through 4 illustrate distance distribution, with value of y axis being the count for each bin.

Table 1. Summary Statistics of Segment Distances for Top 100 OD Pairs

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Orig.to.Ramp	0	0	27.1	82.33	75.2	698.3
Ramp.to.Ramp	628.6	1564	2094	1947	2302	3256
Ramp.to.Dest.	0	0	27.7	66.58	105.4	353.4

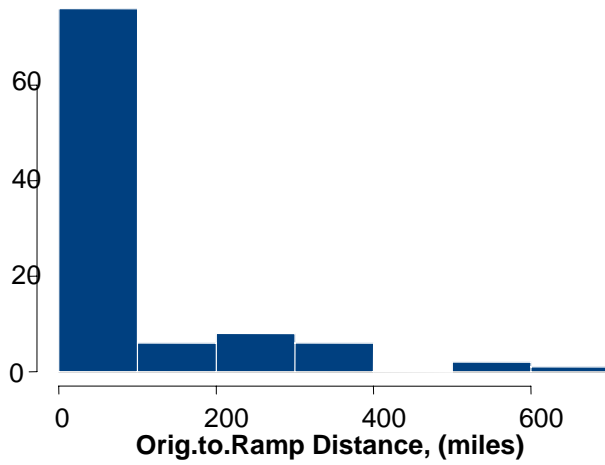


Figure 2. Origin to Origin Ramp Distance Distribution for Top 100 OD Pairs

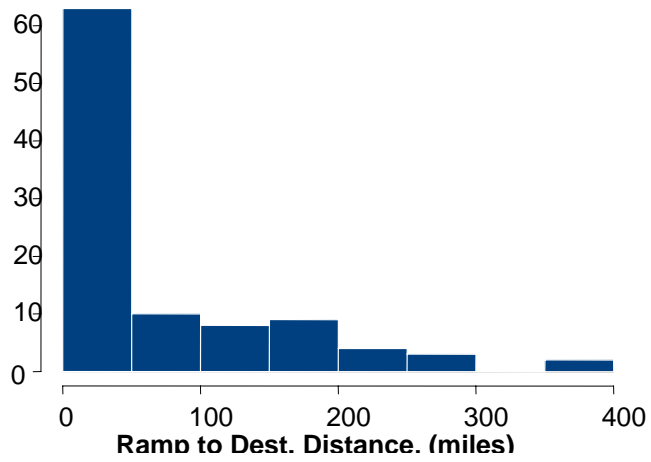


Figure 3. Destination Ramp to Destination Distance Distribution for Top 100 OD Pairs

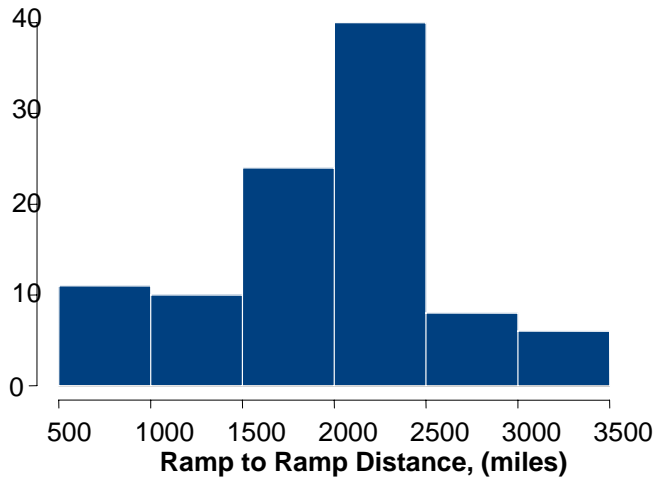


Figure 4. Ramp to Ramp Distance Distribution for Top 100 OD Pairs

The previous results are based on 100 OD-pairs. Since each OD pair has a different number of loads, the distances were also calculated weighted by the number of loads so that the statistics will not be skewed by a few trips that may have extremes with respect to segment distances. The results of average segment distance for all OD pairs weighted by loads are presented in Table 2.

Table 2. Average Segment Distances Weighted by Loads for Top 100 OD Pairs

	Mean Distance (miles)
Orig.to.Ramp	53.00
Ramp.to.Ramp	2047.15
Ramp.to.Dest.	32.36

All OD Pairs

The same analysis was also performed with the whole data sets that include 659 OD pairs. The results are presented in Table 3 and Figures 5 through 7. With all OD pairs, it was found that the mean origin to origin ramp distance is 97.83 miles, the mean ramp to ramp distance is 2035

miles, and the mean destination ramp to destination distance is 106.3 miles. Large percentages of trips have less than 50 miles from origin to ramp or from ramp to destination because the origin and origin ramp or destination and destination ramp are in the same city.

Table 3. Summary Statistics of Segment Distances for All OD Pairs

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Orig.to.Ramp	0	16.9	38	97.83	148.6	698.3
Ramp.to.Ramp	510.2	1579	2127	2035	2475	3378
Ramp.to.Dest	0	22	52	106.3	151.3	1163

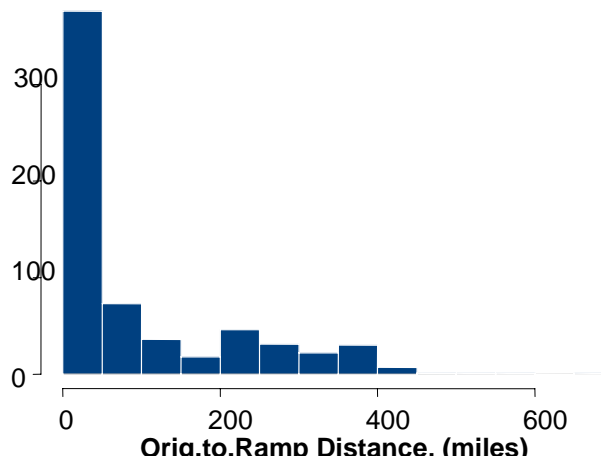


Figure 5. Origin to Origin Ramp Distance Distribution for All OD Pairs

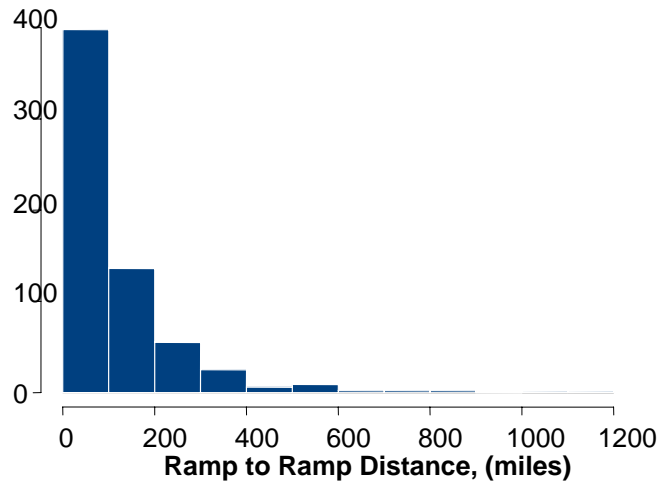


Figure 6. Destination Ramp to Destination Distance Distribution for All OD Pairs

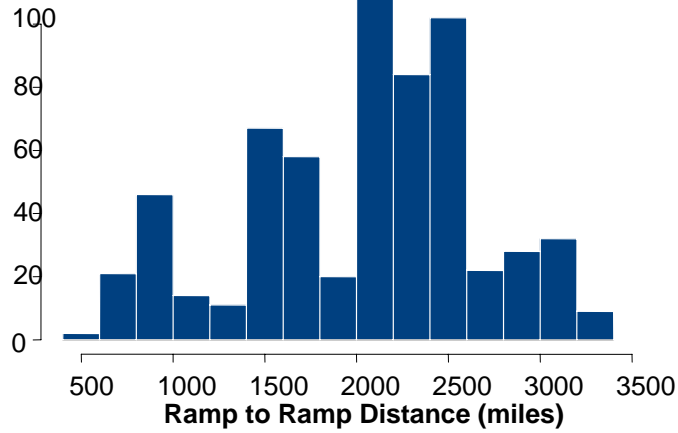


Figure 7. Ramp to Ramp Distance Distribution for All OD Pairs

Again, since each OD pair has different number of loads, the distances were also calculated weighted by the number of loads so that the statistics will not be skewed by few trips that may have extremes with respect to segment distances. The results of average segment distance for all OD pairs weighted by loads are presented in Table 4.

Table 4. Average Segment Distances Weighted by Loads for All OD Pairs

	Mean Distance (miles)
Orig.to.Ramp	58.76
Ramp.to.Ramp	1962.80
Ramp.to.Dest.	46.60

This part of analysis confirmed the commonly accepted view that rail is for long distance hauling. From the data, the distances on rail are all longer than 500 miles. Loads are collected from the vicinity of the origin rail ramps by truck and transported from the destination rail ramps to final destinations again by truck. The trucking distances at two ends are typically short. As a matter of fact, large percentages of the loads are collected from or delivered to by truck in the same cities where the rail ramps are located.

4.2 Intermodal Distance vs. Highway Distance

Comparisons were also made between intermodal trip distances and highway distances. The highway distance is the door-to-door distance if the trip were made via highway exclusively, and the intermodal trip distance is the actual distance for the intermodal trip, which is the sum of distances of origin to origin ramp, origin ramp to destination ramp, and destination ramp to destination.

Top 100 OD Pairs

For the top 100 OD pairs, Table 5 provides summary statistics and comparison between intermodal distances and highway distances, while figures 8 and 9 show distance distribution for highway distance and intermodal distance respectively. Figure 10 shows highway distance vs. intermodal trip distance, while Figure 11 shows the ratios of highway distances to intermodal distances.

Table 5. Summary Statistics for Intermodal and Highway Distances for top 100 OD Pairs

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Highway	678.8	1488	1844	1790	2121	2878
Intermodal	709.9	1763	2232	2095	2504	3296
Ratio	0.5821	0.823	0.8692	0.8633	0.915	1.147

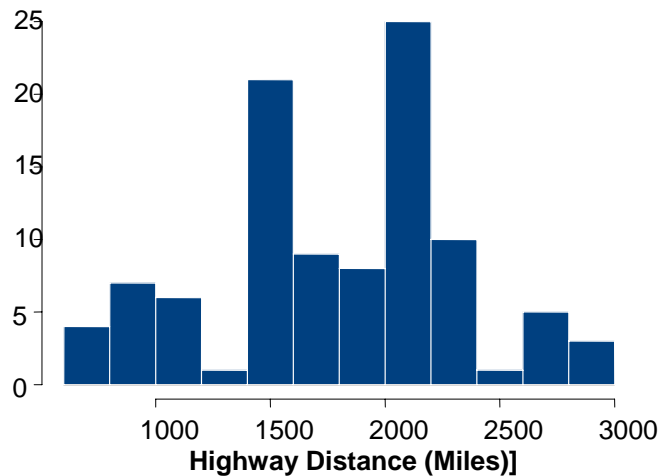


Figure 8. Highway Distance Distribution for Top 100 OD Pairs

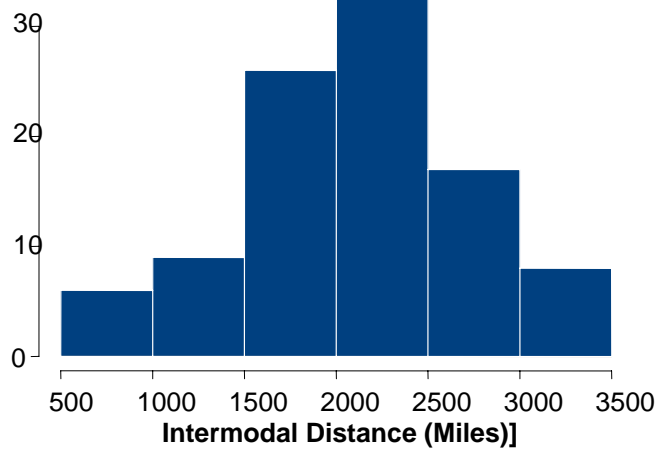


Figure 9. Intermodal Distance Distribution for Top 100 OD Pairs

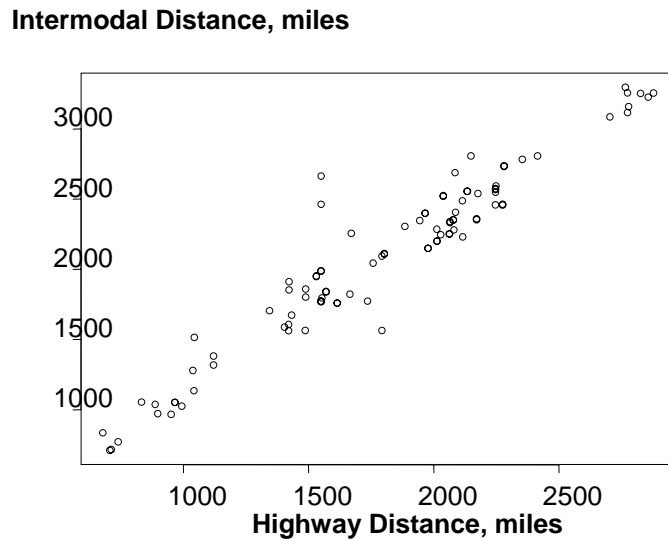


Figure 10. Highway Trip Distance vs. Intermodal trip Distance for Top 100 OD Pairs

Ratio of Highway distance to Intermodal Distance

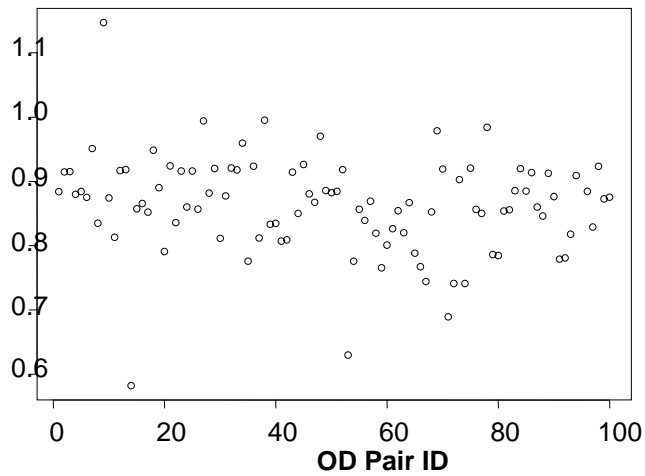


Figure 11. Ration of Highway Trip Distance to Intermodal Trip Distance for Top 100 OD Pairs

All OD Pairs

The same analysis was performed for all OD pairs. For all pairs, Table 6 provides summary statistics and comparison between intermodal distances and highway distances, while figures 12 and 13 show distance distribution for highway distance and intermodal distance respectively. Figure 14 shows highway distance vs. intermodal trip distance, while Figure 15 shows the ratios of highway distances to intermodal distances.

Table 6. Summary Statistics for Intermodal and Highway Distances for All OD Pairs

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Highway:	497.1	1528	1977	1852	2239	2948
Intermodal:	630.1	1806	2364	2239	2649	4082
Ratio	0.3634	0.806	0.8575	0.849	0.8902	2.859

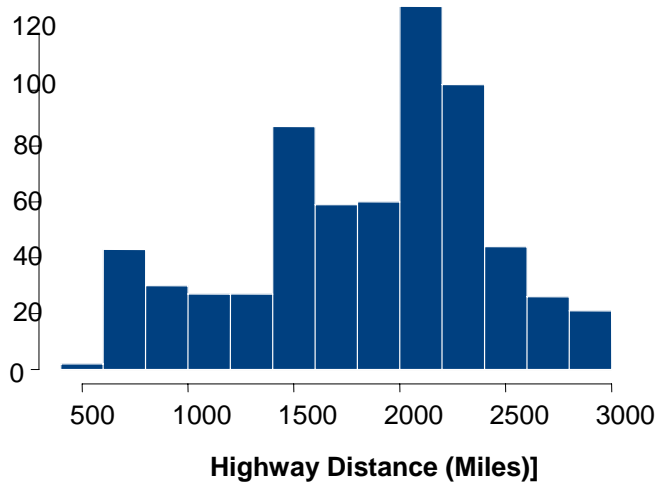


Figure 12. Highway Distance Distribution for All OD Pairs

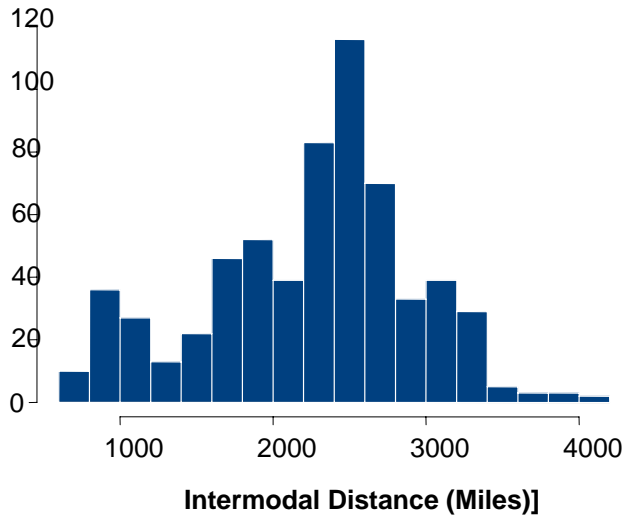


Figure 13. Intermodal Distance Distribution for All OD Pairs

Intermodal Distance, miles

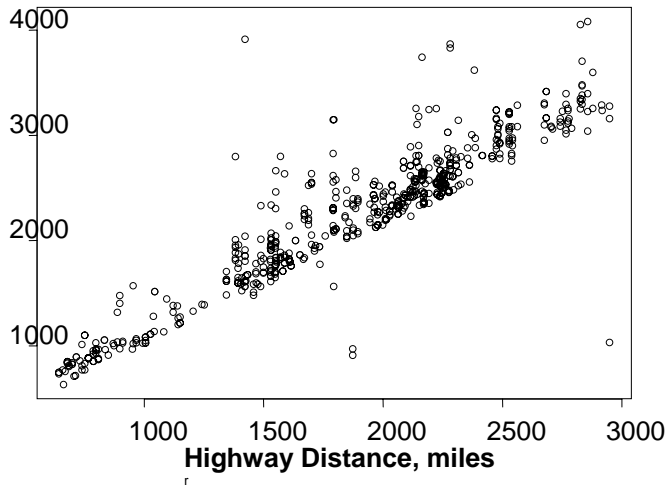


Figure 14. Highway Trip Distance vs. Intermodal trip Distance for All OD Pairs

Ratio of Highway distance to Intermodal Distance

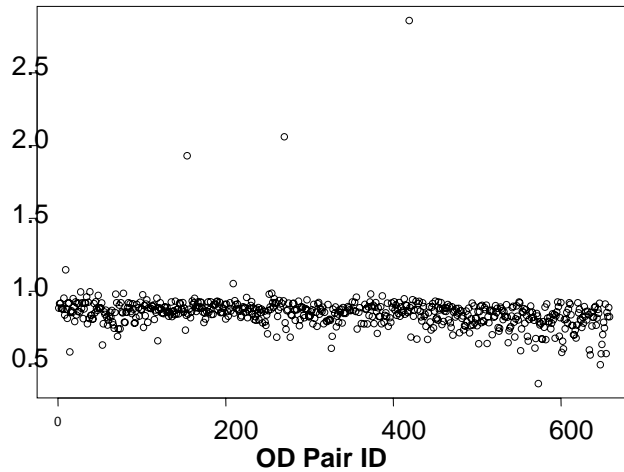


Figure 15. Ration of Highway Trip Distance to Intermodal Trip Distance for All OD Pairs

From this part of the analysis, it is evident that typically highway distance is always smaller than the intermodal distance for a given trip, and the difference on average is about 15%. Figure 15 has a handful of outliers that show high values of highway to intermodal distance ratios. Those could be due to errors in original data.

4.3 Top Origin Ramps and Distance Distribution

Based on the consolidated data of top 100 OD-pairs from 3 companies, 10 origin ramps that generated most number of carloads by the three companies were identified. The names of the ramps and their corresponding carloads are tabulated in Table 7.

Table 7. Top Origin Rail Ramps

Ramp Name	Total Origin Loads
Los Angeles Total	88769
Chicago Total	69676
Tacoma Total	27003
Seattle Total	21392
Houston Total	14491
Bedford Park Total	13667
Baltimore Total	11718
Kansas City Total	11610
San Bernardino Total	11522
Long Beach Total	10375

For those 10 origin ramps, the distribution of the distance from origins to those ramps were also analyzed and the results are presented in Table 8, and the distribution of rail distances from those origin ramps is presented in Table 9.

Table 8. Distribution of Distance from Origins to Top Origin Ramps

OriginToRamp Dist.	0-50	50-100	100-150	150-200	>200 mi.
Los Angeles:	0.94*	0.	0.	0.	0.06
Chicago:	0.67	0.02	0.	0.	0.30
**Tacoma:	1	0	0	0	0
Seattle:	1	0	0	0	0
Houston	1	0	0	0	0
Bedford Park	1	0	0	0	0
Baltimore	1	0	0	0	0
Kansas City	0.65	0.	0.	0.	0.35
SanBernardino	0.49	0.11	0.22	0.17	0.
**Long Beach	0	0	0	0	1

* The numbers in the table are fractions of loads

** denotes that all loads belongs to the same OD Pair

Table 9. Distribution of Ramp to Ramp Distance for Top Origin Ramps

RampToRamp Dist.	<500	500-1000	1000-2000	2000-3000	>3000
LosAngeles:	0	0	0.37*	0.49	0.14
Chicago:	0.	0.13	0.02	0.85	0.
**Tacoma:	0	0	0	1	0
Seattle:	0.	0	0.08	0.65	0.27
Houston:	0	0	1	0	0
Bedford Park	0	0.15	0	0.85	0
Baltimore	0	0.40	0.28	0	0.32
Kansas City	0.	0.17	0.83	0.	0.
San Bernardino	0.	0.	0.33	0.67	0.
**Long Beach	0	0	0	1	0

* The numbers in the table are fractions of loads

** denotes that all loads belongs to the same OD Pair

The results in this part of analysis are consistent with those presented in Segment Distance distribution section. The majority of loads are from the same cities, or the cities in close vicinity, and most of loads will travel more than 1000 miles on rail.

4.4 Top Destination Ramps and Distance Distribution

Based on the consolidated data of top 100 OD-pairs from 3 companies, 10 destination ramps that have most number of carloads coming in by the three companies were identified. The name of the ramps and their corresponding car loads are tabulated in Table 10.

Table 10. Top Destination Rail Ramps

Ramp Name	Total Destination Loads
Chicago	65962
Los Angeles	62441
Bedford Park	31656
Atlanta	16385
Kansas City	15542
Alliance	13066
Croxton	12861
Richmond	12290
Tacoma	11637
Memphis	9796

For those 10 destination ramps, the distribution of the distance from those ramps to the destinations were also analyzed and the results are presented in Table 11, and the distribution of rail distances from origin ramps to those ramps is presented in Table 12.

Table 11. Distribution of Distance from Top Destination Ramps to Destinations

RampToDest. Dist.	0-50	50-100	100-150	150-200	>200
Chicago:	0.50	0.06	0.09	0.10	0.25
Los Angeles:	0.88	0.	0.	0.	0.12
Bedford Park	1	0	0	0	0
Atlanta	0.57	0.	0.	0.30	0.12
Kansas City	0.45	0.18	0.	0.	0.37
Alliance	0.68	0.21	0.11	0.	0.
*Croxtton	1	0	0	0	0
Richmond	1	0	0	0	0
*Tacoma	1	0	0	0	0
Memphis	0.74	0	0.26	0	0

Table 12. Distribution of Ramp to Ramp Distance for Top Destination Ramps

	<500	500-1000	1000-2000	2000-3000	>3000
Chicago:	0.	0.02	0.02	0.96	0.
Los Angeles	0.	0.	0.43	0.57	0.
Bedford Park	0	0.15	0	0.85	0
Atlanta	0.	0.70	0.	0.12	0.19
Kansas City	0.	0.08	0.92	0.	0
Alliance	0.	0.21	0.79	0.	0.
*Croxtton	0	0	0	0	1
Richmond	0	0	0	1	0
*Tacoma	0	0	0	1	0
Memphis	0	0	0.74	0.26	0

Again, the results in this part of analysis are consistent with those presented in Segment Distance distribution section. The majority of loads go to the same cities, or the cities in close vicinity, and most of loads have traveled more than 1000 miles on rail.

4.5 Transactions of Intermodal trips

An intermodal trip will go through mode change, and sometimes carrier change. Multiple transactions associated with each trip are important issues to look into. Theoretically, each transaction can be reported once as a separate trip and that can easily contribute to inaccuracy of the intermodal flow measurement.

The issue of the number of transactions was investigated in the study. We define each of the following scenarios as one transaction:

- A mode change: after a load is transported to origin ramp, it will be load on to the train and that counts as one transaction. At the destination rail ramp, the load will be reloaded on to trucks and that counts as another transaction.
- A carrier change: a rail trip may be completed by more than one carrier due to rail line ownership. A change of rail carriers counts as one transaction.
- Intermediary: if one segment of the trip involves an intermediary, one additional transaction is added in addition to the transaction due to carrier change.

For example, a trip from the origin to origin ramp, goes to destination ramp on single rail, and goes to the destination on truck is considered to involve 3 transactions. If the trip involves one rail carrier change, then the total number of transaction will be 4.

The number of transaction distribution by load is tabulated in Table 13. The results are from the whole dataset that includes all 659 OD pairs with the total number of carloads of 473975.

Table 13. Distribution of Number of Transactions by Loads

# of Transactions	3	4	5	>5
% of Total Loads	81.72	17.17	0	1.10

If the distribution is not by load, rather only by OD pairs, the results are in Table 14.

Table 14. Distribution of Number of Transactions by OD Pairs

# of Transactions	3	4	5	>5
% of OD Pairs	57.67	40.21	2.12	0

It is very important to realize that from the data close to 20% of the intermodal loads will involve more than 3 transactions, and on more than 40% of the OD pairs, more than 3 transactions are involved.

5. SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

Many freight trips are reported as rail trips, such as those reported in the Commodity Flow Survey under the category of rail mode. Those trips are actually intermodal trips. From this study, it was found that at both ends of a rail trip two segments by truck are typically involved and the trucking distance is typically in the order of 50 to 100 miles, and they do not change greatly with the actual travel distance of rail portion. The distance of rail portion is generally longer than 500 miles. With this knowledge of the operation, we can more accurately categorize those “rail only” trips as intermodal trips, and adjust the total intermodal trip distance by adding the highway distances at both ends.

The study also found that intermodal distance is on average about 15% longer than highway distance. This is a useful result for preliminary planning and alternatives comparisons without actually negotiating a contract.

The number of transactions involved in an intermodal trip is something that might have contributed to inaccurate intermodal measurement. There could be a number of possibilities of how a trip is reported:

- Scenario A: each carrier reports the entire trip, and as the result a trip is reported multiple times.
- Scenario AB, each carrier reports its own segment, and the result is that a single trip is reported as multiple shorter trips, and the intermodal element could easily be lost in the process.
- Scenario C: a combination and scenarios A & B. A trip could be reported multiple times, and are also reported as separate trips.

Given that at least three transactions are involved in an intermodal trip and sometimes the number of transactions can be four or five, it is critically important that uniformity in reporting be achieved. One way of solving this problem is to establish a unique trip identification. With a

unique trip ID, duplicated reporting or segmented reporting can be easily identified. The implementation of this idea however requires participation of the entire industry.

Intermodal flow measurement study is a very complicated issue. Even though we got very high quality data from transportation providers and was able to identify a few key issues of intermodal flow data compilation and reporting, there are still a lot of work that needs to be done towards getting truly trustworthy flow measurement. More surveys and studies need to be conducted on how industry is currently collecting data and reporting data. That is critical to find out why flow is currently misreported and by how much, and is also essential to establish a more reliable and truly intermodal measure. The success of development of an accurate way of collecting and reporting truly intermodal flow data will depend on higher level of support and participation from the transportation industry, and the implementation of the new data collection and reporting procedures will require a concerted joint effort of government and private industry.

REFERENCES

- ¹ National Transportation Library. The Intermodal Transportation Efficiency Act of 1991 (ISTEA), accessed at <http://ntl.bts.gov/DOCS/ste.html>.
- ² . Cambridge Systematics and Texas Transportation Institute, Traffic Congestion and Reliability: Linking Solutions to Problems, final report, July 2004.
- ³ Federal Highway Administration, Office of Freight Management and Operations, Freight Analytical Framework (FAF), Advancing Freight in the 21st Century, 2004.
- ⁴ Wilbur Smith Associates, Inc. “*Latin America Trade and Transportation Study, Mississippi Report*”, Mar. 2001.
- ⁵ FHWA Office of Freight Management & Operations, U.S. Department of Transportation. Intermodal Freight Transportation, Volume 1: Overview of Impediments, Data Sources For Intermodal Transportation Planning, And Annotated Bibliography , 1995.
- ⁶ Pierre Arnold , Dominique Peeters and Isabelle Thomas. Modeling a Rail/road Intermodal Transportation System. Transportation Research, Part E 40 (2004) 255–270.
- ⁷ E. D. Kreutzberger. The Impact of Innovative Technical Concepts for Load Unit Exchange on the Design of Intermodal Freight Networks. Transportation Research Board, National Research Council, Washing D.C., 2003.
- ⁸ Rutten, Ben J. C. M. The Design of a Terminal Network for Intermodal Transport. Transport Logistics; Dec98, Vol. 1 Issue 4, p279, 20p.
- ⁹ Germa Bel. Chanbes in Travel Time across Modes and ITS Impaction on the Demand for Inter-urban Rail Travel. Transpn Res.-E (Logistics and Transpn Rev.), Vol. 33, No. I, pp. 43-52, 1997.
- ¹⁰ Ziliaskopoulos, Athanasios. An Intermodal Optimum Path Algorithm for Multimodal Networks with Dynamic Arc Travel Times and Switching Delays. European Journal of Operational Research; 09/16/2000, Vol. 125 Issue 3, p486-503

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- ¹¹ Newman, Alexandra M. and Yano, Candace Arai. Scheduling Direct and Indirect Trains and Containers in an Intermodal Setting. *Transportation Science*; Aug2000, Vol. 34 Issue 3, p256-271.
- ¹² G. Don Taylor, Frank Broadstreet, Timothy S. Meinert and John S. Usher. An Analysis of Intermodal Ramp Selection Methods. *Transportation Research Part E* 38 (2002) 117–134
- ¹³ Ali Haghani. A Model for Designing Container Loading Plans for Containerships. Transportation Research Board, National Research Council, Washing D.C., 2001.
- ¹⁴ Powell, Warren B., Carvalho, Tassio A. Real-Time Optimization of Containers and Flatcars for Intermodal Operations. *Transportation Science*, 00411655, May98, Vol. 32, Issue 2
- ¹⁵ “User Guide for the 1997 Surface Transportation Board Waybill Sample.” Association of American Railroads, Washington D.C., July 1998.
- ¹⁶ Commodity Flow Survey CD-Rom, U.S Department of Transportation bureau of Transportation Statistics. Issued May 2000.
- ¹⁷ Eatough, C.J., Brich, S.C., and Demestsky M. J. A methodology for Statewide Intermodal Freight Transportation Planning, Report submitted by Virginia Transportation Research Council to Virginia Department of Transportation. 1998.
- ¹⁸ Eatough, C.J., Brich, S.C., and Demestsky M. J. A Statewide Intermodal Freight Transportation Planning Methodology, *Transportation Quarterly*, Eno Transportation Foundation, Inc. Volume 54, Number 1. 2000.
- ¹⁹ 997 Economic Census, Vehicle Inventory and Use Survey. U.S. Department of Commerce. December 1999.