ANALYSIS OF INTERMODAL TERMINAL HIGHWAY ACCESS TO ECONOMIC ACTIVITY CENTERS

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ABSTRACT

An area of increasing concern to policy makers is the relationship among intermodal service, terminal location, and the surrounding highway network. Closely tied to these is the need for a better understanding of their impact on the relative costs of intermodal versus single-mode freight movements. To gain insight into this, the authors undertook a series of structured interviews with providers of intermodal services and incorporated the information provides into a simple cost model. The model allows the analyst to examine the boundary conditions between intermodal and highway shipments and to explore how costs affect factors such as terminal location, access difficulty, and shipper distribution about the terminal.

Using the model, three cases were evaluated: (A) variations in customer location, (B) variations in the type of customer pickup and delivery, and (C) changes in terminal efficiency. Cost data were obtained through the shipper surveys; information on catchment areas gathered through a study of the I-95 corridor along the eastern seaboard between the mid-Atlantic states, Jacksonville, Florida, and Atlanta, Georgia; and other sources. In all cases, it became apparent that the drayage and terminal inefficiencies that can be readily absorbed in long-haul moves—1500 to 2000 km (900 to 1200 mi)—cannot be absorbed in the short-haul markets that were studied. Results also identified the importance of the proximity of an intermodal terminal to a shipper. Terminal congestion was found to be a factor in short-haul markets, in which lengthy delays can eliminate the cost benefits of intermodal movement of freight.

INTRODUCTION

Intermodal freight has undergone dramatic growth in the past decade. Increased international trade combined with advances in technology and service improvements have produced an intermodal freight system that uses public and private transport infrastructure to great advantage, which benefits users of the system. The success of intermodal and its potential to achieve a variety of transportation, environmental, and economic development goals have increased its visibility among policy makers. This heightened awareness was acknowledged in the Intermodal Surface Transportation and Efficiency Act of 1991 (ISTEA).

An area of increasing concern to policy makers is the relationship among intermodal service, terminal location, and the surrounding highway network. Closely tied to these is the need for a better understanding of their impact on the relative costs of intermodal versus single-mode freight movements. To gain insight into this, the authors conducted a series of structured interviews with providers of intermodal services and incorporated the information provided into a simple cost model. The model allows the analyst to examine the boundary conditions between intermodal and highway shipments and to explore how costs affect factors such as terminal location, access difficulty, and shipper distribution about the terminal. This paper presents the model developed and some sample results.

The results presented are part of a broader study of the effects of intermodal service on the highway network surrounding the terminal and in congested areas along the route of travel. The broader study focused on a specific corridor along the eastern seaboard between the mid-Atlantic states and Jacksonville, Florida, and Atlanta, Georgia. A freight corridor analysis offers a good opportunity to assess the significance of the different cost components that enter into the choice of highway versus intermodal rail. By improving the understanding of the distribution of intermodal traffic within terminal catchment areas and estimating the relative costs of truck and intermodal, researchers will be able to better assess how changes to intermodal services affect highway congestion, air quality, and infrastructure improvement costs. Of particular interest is the drayage portion of the intermodal trip, because it represents the most direct impact of the intermodal move on the public road system.

INTERMODAL FREIGHT MARKETS AND SERVICE

Intermodal movement of freight generally consists of a combination of local highway movements (drayage) and a rail line-haul movement. The basic advantage of using intermodal service instead of all-highway movement is that it is less expensive to move trailers and containers by railway than by highway. This is primarily because the labor, fuel, and equipment costs per box are much lower for a train than for a tractor trailer. This inherent rail line-haul advantage must be reduced by the cost of moving the box to and from the terminal (drayage) and by the costs of assembling and disassembling the train in the terminal. In recent years, the rail line-haul advantages have increased because of a number of advances, including double-stack technologies and RoadRailer vehicles. Terminal costs have been reduced by closure of low-density hubs, improvements in information systems, and better coordination with major shippers. The result has been that intermodal services are now of great strategic importance to railroads and are used by motor carriers for long-haul movements. The use of intermodal by large trucking firms, such as J.B. Hunt, reflects improvements both in the level of service offered by railroads and external factors, such as the shortage of qualified drivers.

The intermodal market can be segmented into three major user groups: (A) integrated package delivery companies and less than truckload carriers that use intermodal for the line-haul portion of the shipment once loads are consolidated; (B) truck load carriers that substitute intermodal for line-haul truck in some cases to reduce costs and to improve working conditions for drivers, who are in short supply; and (C) intermodal marketing companies (IMC) that book the rail-line-haul and arrange for independent contractors to dray the loads. In some cases, the railroad may perform drayage or own the IMC. Examples of market segment 1 are the U.S. Postal Service (USPS) and the United Parcel Service (UPS), both of which make extensive use of intermodal services. Schneider Transport is an example of a firm in segment 2. Traditional intermodal companies, such as the Hub Group, make up segment 3.

Intermodal Service Characteristics

Intermodal service can be characterized as a hub and spoke system with terminals that concentrate loads for rail line-haul. Intermodal service can be divided into five stages:

1. Drayage to the intermodal terminal (including pickup);
2. Assembly into a train;
3. Railroad line-haul, which may include interchange across carriers;
4. Unloading trailers and containers from the train at the destination terminal; and
5. Drayage to the final destination or consignee.

Each stage of the intermodal shipment has the potential to add some delay. For example, on arrival at the initial terminal, the shipment is held for the appropriate train schedule. Both railroads and shippers have undertaken measures to reduce these delays. Specialized terminal equipment and track configurations can, to some extent, reduce the time required to load or unload a train. Shippers, particularly those that ship high volumes, can influence train schedules and coordinate their pickup and delivery operations with the railroad. Information system improvements are having a substantial effect on reducing the processing times in terminals. The ability of railroads to offer high-quality intermodal service has been documented by Martland and Wang (1), who examined double-stack service across 10 corridors and found that although there is some variability in service among carriers, the overall level of service is generally quite good. The rail line-haul portion of intermodal movements frequently occur at speeds as high as or higher than the legal speed limits for trucks. The same is not necessarily the case for drayage operations.

Drayage Operations

The first and last step in an intermodal trip is to transport the box to or from the terminal. Intermodal providers offer a range of such services, which consist of three types:

- Drop-off and pickup, in which the drayperson leaves an empty trailer or container and picks up a loaded one or vice versa;
- Waiting for loading or unloading, in which the trailer is loaded or unloaded while the drayperson waits; and
- Empt-front or back-haul movements in which the drayperson, who delivers a trailer for loading or unloading and returns without one and makes a second trip at a later time. (This is usually very inefficient, and is becoming rare.)

In any of these schemes, the driver drays the load to the intermodal terminal and, after paper processing, takes the load to a designated location within the terminal for holding or for transfer to rail. At the final

terminal, the driver picks up the load from a designated location and, after processing, drives it to the consignee. At peak periods, gate queues and terminal congestion may add significant delays.

The most efficient drayage operations reported are those of large shippers that manage their own supply of boxes and organize drop-off and pick-up drayage operations to avoid a wait for loading and unloading. Each time a load or empty is drayed to a destination, it is exchanged for another box destined for a terminal. Truck drivers may circulate among several railroad terminals in the same region.

Large contract shippers may be given priority access to trains when they arrive at the destination intermodal terminal and may be allowed to deliver loads after the cutoff time for ordinary shipments. Large truck companies may be willing to accept lower priority treatment in return for a lower rate. Small shippers using third-party operators may experience variations in service levels depending on the demands of larger customers on a particular day.

Mode-Choice Factors

In the past, the competitors to intermodal services were primarily over-the-road trucking companies. Indeed, one of the early concerns among rail executives was how to structure intermodal services to avoid cannibalizing the boxcar market. In recent years, however, the market appears to be a more specialized set of shippers and business partners. Norris (2) reviews the intermodal market and gives specific examples from the shipper community in terms of domestic distributors, exporters, international traders, and food product manufacturers. Common to each of these groups is that users are generally large, have a sophisticated understanding of logistics costs, and are service-sensitive (defined primarily as "predictable service").

Intermodal service competes directly with over-the-road trucking in terms of price and service. Shippers usually make their mode choice based on how price and service affect their total logistics costs (3). Recent studies of shipper behavior suggest that there may be some shippers who are less knowledgeable than others. Vieira (4), shows that shipper perceptions of service may dominate the actual level of service received. Lawrence and Shugart (5) distinguish between sophisticated and unsophisticated customers, and suggest that some seek to either minimize price or transit time rather than calculate their total logistics costs. In any case, the relative importance of price and service depends on a number of shipper-specific factors, such as the value of the commodity being shipped, the costs associated with stock outs, and a firm's general approach to inventory management. Because more firms have moved to just-in-time approaches to inventory and production, the importance of service quality and reliability has increased.

For the longest hauls, intermodal can be as fast and reliable as truck service and less expensive. For the shortest hauls, truck service is generally faster, more reliable, and cheaper. For intermediate hauls, which probably lie in the range of 800 to 2 400 km (500 to 1,500 mi), intermodal service is generally cheaper, but it also is slower and somewhat less reliable. Intermodal service will be attractive to shippers when the cost savings are enough to offset any disadvantages related to poorer service levels.

Intermodal service is priced on a city-pair basis, but the rates by direction may be different. Unlike truck, where back haul is a factor, intermodal rates are not affected as much by the availability of a back haul. Shippers using integrated truck carriers select providers and let them decide the most efficient and effective modal choices, given the price and transit time requirements.

Recent shipper surveys suggest that problems with intermodal service, where it is available, are primarily related to slower transit time, less reliable service, and fragmented responsibility (6, 7). Kang used a logit model to examine shipper mode choice among New York/New Jersey metropolitan area shippers. He concluded that larger companies that ship longer distances and are cost-sensitive are more likely to choose intermodal over truck (8).

These observations suggest that intermodal service, in general, will not be selected if costs are higher than truck. In some cases, imbalanced traffic levels favor intermodal if no back haul is available, even though it is more expensive than truck in one direction. Intermodal also may be selected instead of truck if there are driver shortages over some or all of the trip.

In addition to price and transit time, other factors influence the choice between intermodal and truck. Interviews with intermodal service providers suggest that qualitative aspects of intermodal service may influence choices when the prices and services of truck and intermodal are similar. In particular, if an intermodal terminal is located in an unattractive area with perceived security problems, poorly maintained streets, narrow lanes, difficult turns, or indirect routes or is remote from highway access, intermodal may not be used. Several railroad marketing officials suggest that an intermodal terminal should be near limited-access highways, otherwise use will drop dramatically. Presumably the

cost of difficult terminal access, bumpy streets, and security problems show up as higher drayage costs and increased loss and damage claims for intermodal.

INTERVIEWS WITH INTERMODAL PARTICIPANTS

Detailed information on the most important factors in selecting intermodal over highway is usually difficult to obtain. The presumption of most researchers, and the authors, is that the primary factors are service levels, rates, and total logistics costs (2, 3, 8). To confirm this and to gain insight into other factors that influence mode choice, a cross-section of shippers, third-party IMCs, and carriers were interviewed about terminal access and drayage practices. In addition, field visits were made to terminal facilities in Jacksonville and Atlanta. The participants selected predominantly came from the previously mentioned I-95 corridor study, and in a few cases, participants came from earlier analyses.

Truck access routes to intermodal terminals may follow local streets between designated truck routes and the terminal. Conditions such as street paving, width, lighting, and signage may hinder access. Time-of-day, turn, weight, and commodity restrictions may force trucks to take circuitous routes. Direct routes may not be available in all directions, and alternate routes may not be available in the event that major highway or bridge repairs are required. In addition, security along surface routes can pose problems and impose additional costs on intermodal service providers. However, intermodal users suggested that these issues are not significant in the study corridor and that these issues do not affect their use of intermodal in general. The only corridor-specific issue identified was a situation in Philadelphia in which weight restrictions on alternate routes created problems when bridge reconstruction closed the primary intermodal terminal access route.

Although security in the study corridor is not a major concern among IMCs and carriers, security appears to have become a very important issue. In large urban locations such as Miami and Los Angeles, truck hijackings have become increasingly common. Security problems result in a clearly perceived disadvantage for using intermodal.

Discussions regarding drayage practices were used to define the different drayage scenarios that were applied to the model. Intermodal pickup and drop-off practices have become similar to those used in truck shipping, although drop-and-pick still appears to be more common. The use of assigned pools, in which a group of trailers is assigned to a specific shipper, facilitating efficient drop-and-pick drayage operations, is more common in intermodal than among integrated carriers. However, pools can cause substantial inefficiencies in equipment use, which equipment owners have been attempting to reduce. Waiting for loading and unloading requires drivers to wait, resulting in a cost that can represent a substantial part of the overall cost of a short dray.

Another key element that can have a substantial impact on the economics of intermodal service is how draypersons are compensated. Respondents indicated that compensation is usually determined by the type of dray, with different schemes used depending on the dray's length: hourly rates for short-haul drays, which are typical in urban regions, and distance-based rates for long-haul drays. In some instances a combination of the two schemes may be used (zone-based system). Whereas the former may be provided by company-employed drivers (perhaps with a cartage company or the shipper), the latter most commonly are provided by contracted owner-operators.

TERMINAL LOCATION AND ACCESS ISSUES

Terminal location and access is a key issue affecting private markets and public policy. Railroads take the view that the location of terminals should be based on how best to manage operations and serve customers. Policy makers are concerned with the management of traffic congestion, noise, air quality, and overall land use. Given the size of the freight markets and the important policy issues involved, these differences in perspective have led to conflicts.

The location of intermodal terminals in relation to economic activity is a major consideration for a railroad that must build a large, fixed facility with a relatively long service life. Difficulty in acquiring enough land in a suitable location is a deterrent to relocation of existing terminals, which may be too small or poorly located.

Many intermodal terminals are located on existing railroad property, usually a current or former freight yard. Shippers located along rail right-of-way are no longer constrained to such locations and are likely to relocate to sites close to interregional highway interchanges or locations best suited for local distribution in a metropolitan area.

The best location for reducing traffic flow and congestion may be different from the older sites. In particular, it may be desirable from a highway management perspective to have several intermodal terminals within a metropolitan region, as is the case in Los Angeles, so that traffic can be moved to and from the nearest terminal.

The size of the intermodal market, which is related to terminal location affects service levels. The capacity of an intermodal terminal operation and the frequency of train runs may limit traffic levels. Intermodal rail line-haul times can compete with single-driver trucks but are unlikely to be as fast as team-driver rigs. Highway access and operations improvements to terminal access routes may improve the competitiveness of intermodal services.

A final factor shaping relocation decisions is the market power of very large customers. A number of terminals co-located with the facilities of large customers such as UPS are under consideration or construction. In general, these sites are likely to be attractive in terms of overall highway access and in terms of reducing or eliminating significant over-the-road drayage. There may be a number of current or potential customers, however, for whom the new location will not be as attractive.

A typical intermodal terminal service area is large and may encompass more than one area of concentrated economic activity. The terminal must generate enough traffic to justify train operation in one or more corridors. Although most traffic at a terminal is likely to originate or terminate nearby, within a 50- to 80-km radius, some traffic may reach more remote locations beyond the rail corridors served by the terminal. Competing railroads can be expected to have overlapping terminal service areas, but in some cases a railroad may serve different corridors from different terminals located within the same region.

The authors conducted several studies on the implications of terminal location on road use and on vehicle miles traveled (VMT) to intermodal terminals versus VMT for direct truck movements. In a study of the Southern California region, it was found that because many facilities offer high-quality intermodal services, intermodal dramatically reduced truck VMT relative to VMT for the same shipments moving by truck alone (9). In the study of the I-95 corridor, the authors found similarly large reductions in intercity VMT between origin and destination terminals. In addition, VMT reduction occurred in a number of intermediate cities where truck routes passed through metropolitan areas.

Drayage Efficiency

There are a number of implications to consider when weighing the cost of truck versus the cost of intermodal goods movement. These costs depend upon terminal location and consequent access. These generally appear in terms of the efficiency of drayage to and from the terminal.

If the amount of economic activity in the service area is large and the density of activity close to the terminal is high, most drays will be relatively short. If the terminal cannot be located in the center of economic activity or if the area has a low density of activity, drays will be longer and therefore more expensive. In the northern end of the I-95 corridor, at Kearny, New Jersey, for example, most of economic activity, as measured by employment, is less than 50 km (30 mi) from the terminal. Access, however, is restricted by a limited number of routes to and from New York City. The terminals in Atlanta and Jacksonville are located in areas that are smaller and lower in activity density, which results in a typical dray of 80 to 160 km (50 to 100 mi).

Another important factor is proximity to major contract shippers and truck distribution centers. In some cases, such as in Worcester, Massachusetts, the intermodal terminal is located so that the cost of drayage for UPS is minimized. The cost of drayage is relatively low when loads can be moved between the intermodal yard and a distribution center quickly and there is no need to wait for loading and unloading of trailers. Integrated truckload carriers can optimize drayage movements and short-haul intercity truckload moves, thereby capturing some or all of the savings in drayage, as proposed by Spasovic and Morlok (10). The ability to schedule drayage and combine it with truckload moves is more likely to ensure a back haul and expands the portion of the terminal service area feasible for drayage.

In shorter intermodal corridors, an expensive dray at either end of the trip is likely to result in a price higher than the price for truck movement. The parts of the catchment areas located between terminals usually trigger this condition. In short corridors, the service area is expected to be especially small, with the bulk of the traffic dominated by a few large customers with nearby facilities. Some longer drays may be economical if they extend beyond the corridor and do not increase the disadvantage of drayage relative to truck, if the dray at one end is short, or if the shipment is international. In such short corridors, the quality of terminal access may be crucial to the competitiveness of intermodal transport.

INTERMODAL-TRUCK COST-COMPARISON MODEL

In general terms, long-distance trucking costs are substantially higher than the rail line-haul costs of intermodal service. However, drayage and terminal

costs must be added to the line-haul costs to obtain the total cost of intermodal service. In effect, the break-even distance for intermodal must be long enough for per mile line-haul savings to cover the added costs for terminals and drayage. To gain better insight into the factors that affect these basic elements of truck-intermodal competition, a spreadsheet model was developed. This model allows the user to examine the effect of various factors on the cost of providing either intermodal or all motor-carrier service. The intent was primarily to improve understanding of the boundary conditions between intermodal freight movement and truck movement and to explore their effects on various factors. The factors included in the model reflect the results of structured interviews, industry data, and elements of models previously developed by the authors. In addition to the cost analysis, truck and intermodal transit times were estimated for purposes of service-level comparisons.

The model comprises a series of components that allow users to specify information regarding the origin and destination and some general parameters. The model focuses on operational differences between truck and intermodal so that administrative, marketing, and regulatory costs are assumed to be equal across the modes.

Truck Performance Component

The truck performance component calculates the cost per mile for a truck trip based on a number of factors, including the following:

1. Distance, with a distinction made between intercity highway mileage and mileage on local access roads to and from the highway system.
2. Labor costs measured in either cost per mile, usually done for interregional operations, or cost per hour, usually done for local operations.
3. Fuel costs based on fuel efficiency on both local and highway mileage.
4. Driving speed over the local and highway network estimated from speed limits on the selected routes in the Oak Ridge U.S. highway network.
5. Wait time for loading and unloading at the origin and destination and a requirement that the pickup and delivery be made at a time specified by the shipper and consignee. That is, if the shipper specified that the delivery is to be made at 1800 hours, if the driver arrives at 1400, he must wait an additional 4 hr.
6. Back-haul factors specified as a percentage of trip length that must be traveled to acquire a new load. If the trucker has no back haul available, the figure would be set at 100 percent, and if there is always a back haul at the same consignee, the figure would be 0 percent. Generally, the figure used was set at the 25 to 50 percent range.
7. Equipment costs, including a charge per day for the tractor and trailer and a per km charge associated with its use. These figures, obtained from some of the providers interviewed, were tested for consistency with current purchase costs for new equipment.
8. Utilization factors, which account for the time the trailer typically is held by consignees before loading and after unloading.

These factors were then used to determine a set of truck performance measures for a given origin-destination pair. The performance measures include the total cost of the trip, cost per mile, loaded trip time, and cycle time for tractors and trailers. In addition, costs were derived for fuel, drivers, equipment such as tractors and trailers, etc.

Intermodal Performance Component

The intermodal performance represents the sum of the drayage and the rail elements that together constitute an intermodal service offering.

Drayage Performance

The drayage component is similar to that of the truck submodel discussed previously, with several notable exceptions. Drayage parameters include terminal access time and operating hours to account for delays that may be incurred at the intermodal terminal. A peaking factor for gate queues is not explicitly modeled but can be included in the terminal waiting time. The drayage component generates essentially the same performance measures as the truck submodel, which are then summed into the overall intermodal submodel.

Rail Performance

The rail component estimates the costs and service levels for both the rail line-haul and terminal portions of intermodal movements. The rail line-haul portion calculates the costs and determines service based on a set of per mile costs and average speeds over the rail network. In addition, it determines whether levels trailers connect with the train schedule. If a connection

is missed, the shipment is delayed until the next scheduled train departs. In very busy corridors where three or more trains depart daily, missing a scheduled connection may not be a serious problem. In the mid-Atlantic corridor, service was one scheduled train per day in either direction.

Terminal parameters include lift time, loading and unloading, ordinarily expressed as a minimum cutoff time. Availability of trailer-container storage space is not explicitly modeled, but it should be noted that in a congested yard, storage may affect the speed of operations, and in some cases, the boxes will have to be moved to a secondary storage location for later pickup.

RESULTS

In this section, results of applying the model to three illustrative cases are presented. The origin-destination pairs examined are from the previously mentioned I-95 corridor study of the eastern seaboard. The cases represent examples of all-highway shipping versus intermodal shipping and are based on varying geographic locations and varying pickup and delivery practices used by different types of intermodal customers. Following the cases are:

1. Variations in customer location. In this case, three scenarios were considered: (1) the shipper/consignee is located near the intermodal terminal on each end of the move (which we would expect to be most favorable to intermodal movements); (2) the shipper/cosignee is located away from the intermodal terminals and requires a reverse move to and from the intermodal terminals; that is, the highway distance is less than the rail mileage (which we would expect to be an unfavorable situation for intermodal); and (3) the shipper/cosignee is beyond the corridor, in effect extending the corridor.
2. Variations in the type of customer pickup and delivery. Three types of drayage were discussed in the section on drayage operations. The two most common types—drop and pick and waiting for loading and unloading—were examined with the model.
3. Changes in terminal efficiency. The most common concern expressed by interviewees was congestion at terminals. Apart from the obvious impacts on timely pickup and delivery, terminal congestion can have a significant impact on the cost of providing intermodal service. Draypersons handling short-distance metropolitan deliveries usually are compensated on an hourly basis, such that unproductive time spent waiting at terminals can quickly turn into a substantial portion of the overall drayage cost.

Data Used in Cases

The data used in the analysis come from the I-95 corridor study cited earlier and is based on the services operated in 1991. The New Jersey to Atlanta and Jacksonville, or mid-Atlantic, corridor carries high highway traffic volumes and is competitively served by Norfolk Southern and CSX. Intermodal volumes relative to truck volumes were found to be modest, in part due to the relatively short trip lengths within the corridor. Philadelphia to Jacksonville is a distance of 1 454 km (887 mi) by rail, and the Philadelphia to Atlanta distance is 1 257 km (767 mi) by rail. Other major terminals in the corridor are located at Kearny, New Jersey, and Alexandria, Virginia. Shipments within this corridor fall into the lower range of rail line-haul distance considered competitive for intermodal.

The 1991 Interstate Commerce Commission (ICC) rail waybill sample provided data on volume of intermodal shipments between railroad terminals in the corridor, but no information about actual shipment origins and destinations. The terminal pairs in the corridor with significant corridor traffic were identified, but not all major terminals located in the study area handled corridor traffic. At Kearny and Baltimore, corridor traffic formed a minor portion of total traffic.

Intermodal terminals were located on the Oak Ridge U.S. highway network, and terminal service areas were estimated by partitioning the network. The U.S. Economic Census Data on Manufacturing Employment (11) was used to allocate drayage to destinations in each terminal service area (9) by ZIP code. Least-cost routes were determined to compare intermodal truck shipments with alternative, direct truck shipments from the region.

The terminal service areas in the corridor were found to be large, suggesting that traffic is relatively undeveloped or that not all locations in the corridor are competitively served. In the southern part of the corridor, lower density of development results in longer drays and a lower proportion of short drays. This spacing of terminals is large, compared with the more concentrated and compact metropolitan areas at the northern end of the corridor.

Cost-Model Factors

Unit costs typical of actual operations were used in the model, but no attempt was made to calibrate them for any specific operation. In the truckload model, the following cost elements were applied to all cases:

- Tractor ownership cost: $40/day;
- Tractor maintenance cost: $.124/km ($0.20/mi);

TABLE 1 TRUCK AND INTERMODAL COST COMPARISON

Origin	Destination			Truck Cost	IM Cost	Cost Ratio	IM Savings	Truck KM	Dray KM	Avoided KM	Rail KM	Intermodal Circuity
"Standard" Drayage												
Kearny, NJ	**Atlanta, GA**											
New York, NY	10013	Atlanta, GA	30377	$791	$647	81.84%	$144	1392	21	1371	1365	1.00
Somerville, NJ	08876	Gainesville, GA	30501	$736	$757	102.85%	($21)	1279	146	1133	1365	1.18
Mt. Vernon, NY	10550	Opelika, AL	36801	$881	$795	90.21%	$86	1588	203	1385	1365	0.99
Kearny, NJ	**Jacksonville, FL**											
New York, NY	10013	Jacksonville, FL	32206	$842	$715	84.94%	$127	1498	31	1467	1558	1.06
Edison, NJ	08817	Valdosta, GA	31601	$849	$868	102.18%	($19)	1516	225	1291	1558	1.18
Smithtown, NY	11787	Sanford, FL	32771	$985	$931	94.51%	$54	1770	298	1472	1558	1.05
Alexandria, VA	**Atlanta, GA**											
Newington, VA	22122	Atlanta, GA	30377	$619	$535	86.36%	$84	1020	19	1001	1006	1.00
Funkstown, MD	21734	Gainesville, GA	30501	$591	$709	120.09%	($119)	956	220	736	1006	1.28
Baltimore, MD	21224	Opelika, AL	36801	$737	$728	98.77%	$9	1270	253	1017	1006	0.99
Alexandria, VA	**Jacksonville, FL**											
Arlington, VA	22209	Jacksonville, FL	32206	$671	$603	89.81%	$68	1141	31	1110	1197	1.08
Winchester, VA	22601	Valdosta, GA	31601	$725	$830	114.54%	($105)	1252	311	941	1197	1.20
York, PA	17403	Sanford, FL	32771	$828	$872	105.38%	($45)	1477	370	1107	1197	1.06
"Efficient" Drayage												
Kearny, NJ												
Jersey City, NJ	07302	Atlanta, Ga	30377	$789	$620	78.57%	$169	1389	19	1370	1365	1.00
Jersey City, NJ	07302	Jacksonville, FL	32206	$840	$685	81.52%	$155	1495	29	1466	1558	1.06
Alexandria, VA												
Capitol Heights, MD	20743	Atlanta, Ga	30377	$565	$522	92.30%	$44	1046	42	1004	1006	1.00
Capitol Heights, MD	20743	Jacksonville, FL	32206	$611	$586	95.97%	$25	1151	51	1100	1197	1.08

- Trailer ownership cost: $10/day;
- Fuel cost: $.21/L ($0.80/gal), 3.4 km/L (8 mi/gal) on highways, and 1.7 km/L (4 mi/gal) on local streets; and
- Driver cost: $.19/km ($0.30/mi).

Truck and trailer cycle times were calculated based on assumptions concerning trip distance, average speed, pickup and delivery times, hours/day for driving, trailer detention time at the destination, and empty mileage associated with the load. For the study corridor, typical cycle times for a tractor were in the range of 1.5 to 3 days; typical cycle times for the trailers were 4 to 8 days.

Using this model, truck costs were estimated to be in the range of $0.52 to $0.62/km ($0.85 to $1.00/mi) for origin-destination movements in the corridor. These costs are consistent with common perceptions of operating costs for advanced truckload carriers.(12)

The intermodal cost model included submodels for drayage and the rail line-haul. The rail model included the 2 most important cost elements that reflect reasonably efficient operations:

- Terminal costs: $25/lift at original and destination terminals; and
- Rail line-haul costs: $0.31/container-km ($0.50/container-mi).

The drayage model was structured to provide costs that are consistent with published prices (7) and the experience of shippers and IMCs. It included three cost elements:

- Fixed cost per trip: $40;
- Operating cost/km (mi): $1.24 ($2.00) for local streets, $0.62 ($1.00) for urban highway, and $0.43 ($0.70) for interstate; and
- Operating cost/hour: $20.

The cycle time for drayage was based on travel time, terminal time, and pickup and delivery time. The most efficient situation for drayage is a 3.2-km (2-mi) round-trip movement with a cycle time of 1 hr; the predicted cost in this case is $62, which is equivalent to the lowest price we have heard quoted for a short drayage (although the costs for high-volume rubber interchange conducted on a contract basis can be less than $40 per trailer). More typical for a short dray is a 16-km (10-mi) round trip with a 2-hr cycle time. The predicted drayage price in this case is $90 to $100, depending on the portion of the move that is on local streets. This is equivalent to the drayage prices that we have heard quoted for short-distance movements between a port and a nearby railyard. Drayage costs rise rapidly with the length of haul and the drayage cycle time. For a 320 km

(200 mi) round-trip dray with no back haul that requires a drayperson for an entire 8-hr day, the predicted price is approximately $400. If a back haul is available, the predicted price drops by almost 50 percent. These prices are consistent with rates we have heard quoted by various intermodal operators.

Results for the Three Cases

Table 1 summarizes some results from the model. The first section (Standard Drayage), represents the traditional approach to drayage and considers the three scenarios, in order, for the first case outlined previously. The second section of the table (Efficient Drayage) represents the performance of typical drayage as practiced by high-volume carriers such as USPS or UPS, with hubs located near the terminals and high use of equipment and draypersons. For all cases shown, a drop-and-pick style operation was assumed. Furthermore, for the standard drayage section, an assumption was made that each load generates a similar length, empty-drayage haul to account for trailer repositioning, etc.

Not surprisingly, for each terminal pair, the greatest cost savings occur when drays are kept to a short distance. Also, these savings increase substantially as the length of the rail portion increases. The results for Alexandria underscore the difficulty of providing cost-competitive service in relatively short corridors. Least surprising were the cost results for the reverse-direction moves (second scenario), in which intermodal is not cost-competitive, particularly from Alexandria. The cost advantages of rail haulage appear again with the significantly lower loss for Kearny.

Finally, extension beyond the corridor produces perhaps the most variable results. From Kearny, the cost of an intermodal move is less than the comparable all-truck move, but not to the extent that is possible with a short dray. With the shorter rail line-haul from Alexandria, the results worsen considerably, due to the shorter rail line-haul that must absorb the long drayage costs.

Results for the efficient drayage operation were similar, with an improved back-haul ratio having a modest impact on the difference in cost (see New York to Atlanta and Jersey City to Atlanta in the table).

The impact of terminal congestion on intermodal cost (case 3) also was calculated. A 1-hr wait by a drayperson at a rail terminal for pickup or delivery was found to cost approximately $25. This cost can escalate if the delay results in an outbound trailer missing its train. A similar cost can be incurred if a drayperson must wait at a customer site for pickup or delivery. The results in the table demonstrate that additional waiting time can have a direct bearing on the cost of intermodal service. This is less of a problem with longer hauls.

CONCLUDING REMARKS

Intermodal freight transportation has achieved its greatest success in long-haul markets, where its low costs and reliable service allow it to absorb delays and costs associated with terminals and drayage. On short hauls this has not been the case, and intermodal's success has to a large extent been limited by this issue. Based on previous market descriptions and interviews with market participants, the authors built a relatively simple cost model that examines the impact of various factors that influence the selection of intermodal versus all-highway movement. The model was tested on a corridor for which data were available from a related study. The results support generally accepted hypotheses regarding mode choice. In particular, terminal location relative to the origin and destination are critical.

There are two primary effects of terminal location. First, the terminal location relative to the existing industrial infrastructure determines the drayage distances and cycle time required for drayage. Because drayage costs rise rapidly with the cycle time, intermodal transportation is most attractive to customers located close to intermodal terminals. In the situations examined, intermodal transportation was always less expensive than truck transportation if customers were located close to terminals, thereby minimizing drayage costs. This suggests that terminals should be located near the potential market, terminals should be located where there is room for major customers to locate their facilities, and multiple terminals provide better opportunities to customers than a single, centralized terminal.

The second effect of location concerns the direction of the drayage. If the drayage is in the direction of the truck move, there is only a modest penalty for using intermodal, reflecting the higher costs of using la local rather than an intercity trucker. On the other hand if it is necessary to backtrack to reach the intermodal terminal, another penalty results because the intermodal trip will be longer than the truck trip. In the cases studied, long drays did not necessarily make intermodal uncompetitive, but only if they did not require backtracking. If it was necessary to backtrack at each end of trip, the intermodal option was always more expensive than direct trucking.

It appears that the organization or structure of drayage movements is an important factor in selecting mode choice. This is consistent with other studies (10)

and helps explain why drayage companies and IMCs generally offer several distinct types of services. It also suggests that research into specific boundary conditions between various drayage types may be useful in predicting intermodal volumes and levels of service within markets. The model appears capable of estimating boundary distances.

In addition to the model and results, the process resulted in some general insights regarding traffic congestion, air quality, and terminal security. To a large extent, these factors do not influence intermodal customers, who will use a facility as long as it is cost-effective and it is not too difficult to reach. Security within the intermodal terminal is important, but the quality of access is not critical, except when it affects the cost of drayage. Traffic congestion and congestion within the terminal is relevant to customers because these factors affect the cycle time required for drayage.

Although air quality does not enter into mode choice, it is a major concern for public agencies. Intermodal operations can reduce truck travel within air-quality districts. The customers most likely to use intermodal are located close to terminals, which means that only a short truck move is required and air quality is not compromised. The other group of customers that might use intermodal are those with long drays in the direction of the truck move. In general, these moves require a dray within an air-quality district, as opposed to a truck move through the district; therefore, air quality is not affected.

From a public policy perspective, it is important to promote the location of intermodal terminals at several key locations throughout each metropolitan area to provide the maximum potential for reducing traffic congestion and enhancing air quality. Locating terminals so that they are readily accessible by large trucks will minimize disruption to other traffic, reduce drayage cycle times, and reduce the break even distance for intermodal movements.

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