Using Marginal Costs To Evaluate Drayage Rates in Rail-Truck Intermodal Service

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An operations planning model of the highway portion, or drayage, of rail-truck intermodal transport is used to develop pricing guidelines for drayage service. The model, originally developed and used to evaluate the potential of reducing cost and improving service quality of drayage, also generates marginal (incremental) costs of moving loads in the drayage operation. The marginal costs are used to evaluate the efficiency of drayage rates charged by truckers in the current operation as well as rates used in a proposed operation with centralized planning of tractor and trailer movements. The insights gained from this analysis are used to develop guidelines for using marginal costs in the areas of pricing intermodal door-to-door movements, load solicitation, and decisions regarding load acceptance. Application of the model as a decision support tool for assisting intermodal management in developing proper strategies for pricing and marketing of intermodal service is illustrated. The need for railroad management to become aware of the characteristics of drayage operation and the systemwide impacts of drayage movements on the cost and thus profitability of intermodal operation is indicated.

The use of an operations planning model of the highway portion, or drayage, of rail-truck intermodal freight transport for developing pricing guidelines for drayage service is described. In rail-truck intermodal operations, highway trailers or containers are moved by rail in line-haul between rail terminals and by tractor-trailers from the terminal to receivers (termed consignees) and from shippers to the terminal in the service area. The local tractor-trailer movement is referred to as drayage—the term coming from the earliest such movement, wherein the freight was hauled in wagons pulled by dray horses. Currently, despite its short distance compared with the rail movement, drayage accounts for a large fraction of intermodal origin-to-destination costs and is a major factor in service quality as perceived by shippers. Various railroad industry estimates indicate that the prices paid for drayage for a typical 1,000-haul is 40 percent of the total door-to-door rate (*1*). This high drayage cost is widely regarded by intermodal and railroad executives as a major factor preventing intermodal from becoming competitive with intercity motor carrier in short- to medium-haul markets and inhibiting the profitability of longer movements.

Research was undertaken to evaluate the potential of both reducing cost (and hence price) and improving service quality of drayage (*2*). The central part of the research was the development of a detailed mathematical model of drayage that was used to evaluate cost savings of an operation in which the movements of trailers and containers are centrally planned compared with the current decentralized drayage operation. Drayage companies (truckers) would be paid rates that are based on their costs. The research findings revealed that substantial cost savings could be achieved by introducing a centralized operation (*2,3*).

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However, the primary motivation for this paper was to use the marginal costs of drayage (generated by the model) to evaluate the current drayage rates that are charged by truckers to move trailers. Intermodal service is typically marketed through separate organizations, called intermodal retailers or third parties, who are the actual agents arranging for the transportation. Whereas there are some important recent exceptions to this arrangement, such as in the case of Conrail Mercury service and the QUANTUM service offered by the Santa Fe and J. B. Hunt, third-party retailing remains the dominant form for most domestic intermodal. The intermodal retailers also arrange directly with separate trucking companies for the drayage of trailers (or containers) at the rail terminals. The railroad does not deal directly with the shippers and consignees and in effect receives a division of revenue for the line-haul portion of the service. Because of this pricing arrangement, it is important for the railroad to understand the costs of the drayage operation so that it can properly establish its line-haul rate.

A second purpose was to examine the pattern of marginal costs to ascertain how they varied by direction and location and whether there were any stable patterns. This is important, for if they vary in a seemingly random manner, a marginal cost-base pricing scheme would yield vacillating rates that probably would be unacceptable for both carriers and shippers. Also, profitability of individual loads would be difficult to determine a priori. On the other hand, stable marginal costs would provide an important input to price setting and should prove valuable in establishing a pricing strategy vis-à-vis competitors.

A third purpose was to use the model to evaluate the rates the draymen would be paid in a centralized operation as a measure of the true cost (marginal cost) of tractor and trailer movements. The objective here was to find out whether the rates were smaller or larger than the model-generated marginal costs of trailer movements in the least cost drayage operation. Often in complex transportation systems characterized by load imbalances and terminal congestion, the movement of an additional shipment (trailer) may result in a substantial increase in the cost of operation. This cost may be significant and exceed the rate charged for the movement. Alternatively, it could add little to the overall cost. If the railroad were to introduce centralized operation of drayage and presumably along with that set the origin-to-destination rate for each intermodal shipment, the actual costs of drayage should be the basis for paying for the drayman and for the overall shipment price. Thus, the objective was to ascertain whether the rates represented a good approximation of incremental costs. If so, they would provide an easy-to-use and stable basis for payment. If not, the payment scheme would have to be more complex, perhaps involving assessing the incremental cost of each drayman for each movement. Similar considerations would apply to the inclusion of the cost of drayage in the pricing of the origin-to-destination movement.

BACKGROUND

Intermodal has great potential to offer shippers a competitive product—in terms of price and level of service—by combining the best features of both modes: the efficiency of truck in local operation with the economy of scale of rail in a long haul (*4–6*). Despite these facts, intermodal has not yet achieved its full potential either in terms of increasing its market share relative to its prime competitor, intercity motor carriers, or profitability. As stated by Allen, it has been "a great revenue business but a poor net revenue business" (*7*).

Fragmented Structure of Drayage

A critically important characteristic of intermodal services, which has a major impact on the cost and service quality of intermodal, is the fragmented organizational structure associated with rail-truck movements. As was mentioned earlier, in the case of all shippers except for very large ones, such as UPS and the U.S. Postal Service, and selected services, intermodal service is marketed through intermodal retailers. The intermodal retailers' pricing arrangements between the railroad and drayage are kept confidential. It has been noted that the agents in the system often have different profit/level-of-service frameworks in which they operate (*8*). Thus, they could be attempting to maximize their own profits rather than cooperating in maximizing the profit of the entire intermodal system. In this context, excess profit could be generated by intermodal retailers or drayage carriers, or both, by charging for their service a rate in excess of their incremental costs. Many years ago, Allen (*9*) suggested that the high cost of drayage could be a result of inefficient fragmented operation as well as excess profit extraction by the partnerships between the drayers and the intermodal retailers.

The lack of coordinated pricing and marketing of the overall service, where it exists, is facilitated by the lack of knowledge on the part of the railroad about the drayers' cost structures. An early study of intermodal rail pricing strategies by Horn (*10*) evaluated the efficiency of railroad intermodal rates and analyzed how these rates related to the railroad's overall pricing strategy. His findings indicated that there were no consistent pricing objectives that the railroad followed in deriving its line-haul rates. In addition, the study pointed out that there was no knowledge about the draymen's operating practices and cost structure. This lack of knowledge resulted in the origin-to-destination rate (combined railroad line-haul plus drayage rate) either being lower than it need be considering the competitive truck rate or being higher than the competitive truck rate, driving business to the truckers. Horn suggested that the railroad reevaluate its pricing policies and bring them in line with its marketing and management objectives. Otherwise, there would be no further penetration of intercity truck markets and thus no substantial growth in market share or profit for intermodal. Since pricing must be based on both competitive factors and costs, these results and conclusions underscore the importance of the type of cost analysis described in this paper.

Inefficiencies in Drayage Operation

In addition to these pricing and marketing problems, the fragmentation prevents efficient operation of the entire drayage function. In a typical intermodal market, around the rail terminal, there are at least a dozen intermodal retailers and as many truckers. As a result, drayage is characterized by a large percentage of nonrevenue movements, which contribute to the high cost of operation. For example, it is not uncommon to find one drayman, working for one retailer, delivering a loaded trailer to a consignee in a particular town, waiting while it is unloaded, and then returning the empty trailer to the terminal, while at about the same time another drayman is hauling an empty trailer to a shipper in the same area for loading and then bringing it back to the terminal loaded. Half of each round-trip thus is to move an empty trailer. If information on all deliveries and loads were available at a single location and delivery and pickup schedules were coordinated, these two round-trips might be replaced by one: delivering the loaded trailer, unloading it, repositioning it to the shipper, loading it, and returning to the terminal with a full load. Thus unproductive movements could be reduced or even eliminated if the trailer movements are planned as a whole instead of in a fragmented manner. This efficiency would result in an operation with increased loaded (revenue) miles and thus a lower cost of operation.

The operation of drayage and its pricing are also closely interrelated. As the operation becomes more coordinated using single tractor round-trips to serve more than one load, pricing becomes more difficult. The reason is that costs are no longer essentially only direct in the sense that blocks of tractor (and driver) time (or activities) are associated with single loads. Instead, costs are shared, requiring a more sophisticated determination of costs attributed to each load (trailer).

To understand this, it is necessary to consider the drayage process in more detail. In drayage operations, loaded trailers (or containers loaded on flatbeds or skeleton trailers) are moved from the rail yard (upon their arrival by rail) to the consignee as well as from the shippers to the rail terminal for loading onto trains that carry the trailers to the destination area, from which drayage is used again for final delivery. In addition, once the trailer is emptied by a consignee, it is either moved back to the terminal, from which it will be taken later to a shipper, or repositioned directly from the consignee to a shipper needing an empty trailer for loading. Since the trailers are entirely separate from the tractors, tractors with drivers must be scheduled to support all trailer movements. Furthermore, there may be considerable movement of tractors without trailers, termed bobtailing. The separability of tractor and trailer modules permits trailers to be moved according to two procedures: stay-with and drop-and-pick. The stay-with procedure means that the tractor stays with the trailer during unloading and loading. The drop-and-pick procedure means that the tractor leaves the trailer during unloading or loading and departs to some other location for another assignment. A tractor eventually returns to pick up the trailer and take it to the terminal, or, if the trailer is empty, the tractor can reposition it to a shipper. Discussions with persons in the industry suggest that almost all movements now appear to use the stay-with procedure.

At the present time, the prices charged by draymen are based primarily on the assumption that each trailer delivery is undertaken independently of other deliveries. Thus, as in the earlier example, a tractor delivering a load will return the empty trailer to the terminal rather than pick up an outbound load on the return trip. Since the tractor's time and mileage on the round-trip are uniquely associated with the one delivery, the attributable cost is easily determined, and the price is set slightly above that cost, factoring in overhead and other nondirect costs. Similarly, drop-and-pick rates would then involve two round-trips, so they would be almost twice as high (the reduction being due to saving the loading or unloading time). Indeed, some drayage firms (and some railroad drayage subsidiaries) charge double for this service (perhaps partly to discourage its usage). In practice, prices could deviate from these levels, as economies and diseconomies appear. As for economies, some retailers and draymen would notice opportunities to move loads in both directions on a round-trip.

The basis for pricing under centralized operation, in which multiple loads may be moved by a tractor during one round-

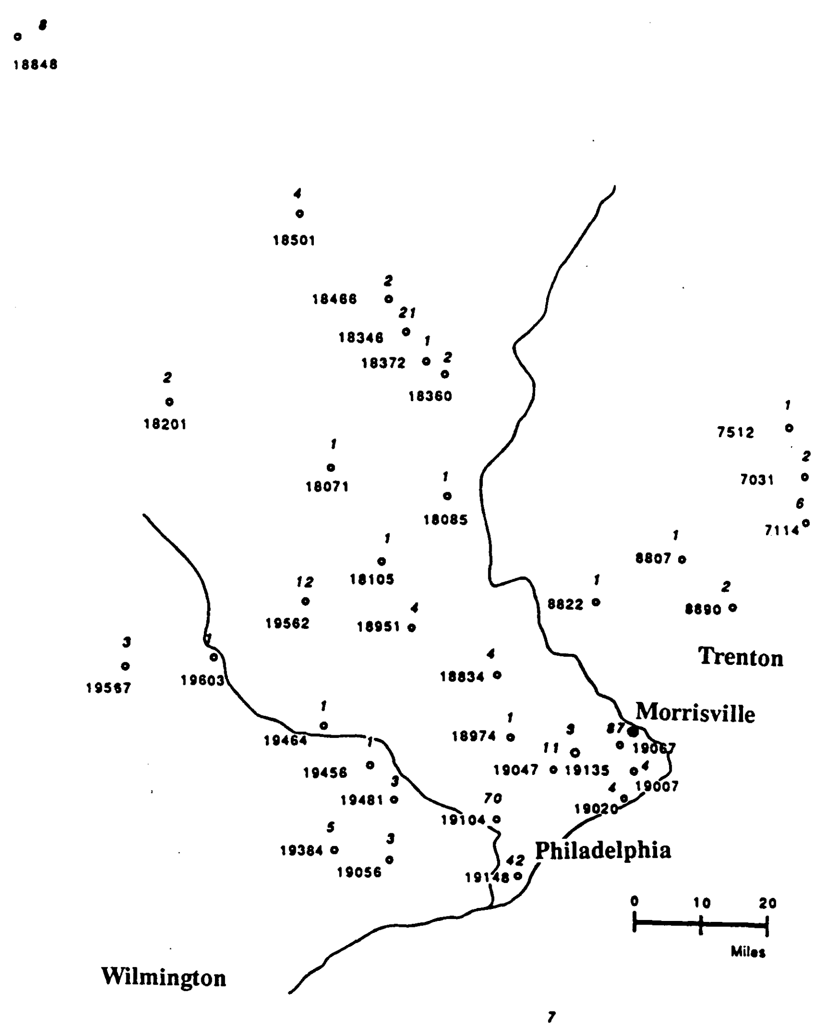

FIGURE 1 Morrisville intermodal terminal service area.

trip from the terminal (perhaps stopping at two or more shipper/consignee locations), is more difficult. The cost of such a round-trip (perhaps including an allocation of unproductive time as well) could be allocated to the loads handled, but this would result in substantial variations for any one load—depending on the availability of other loads to marry with it. This would play havoc with stable pricing. Another approach is to calculate the actual marginal cost of loads to (or from) each area served on the basis of typical or expected traffic patterns. Prices would then be set at or above the marginal cost, thus reflecting market conditions and the possible need for unit revenue in excess of marginal costs in order to cover fixed costs (i.e., total revenue must be at least equal to total cost for the system to be self-sustaining).

Envisioned Drayage Operation

As stated previously, the improved drayage operation envisioned centralized drayage operations planning in which tractors would be assigned to support trailer movements to (*a*) meet service requirements for timely delivery of trailers to and from shippers and consignees and (*b*) minimize the cost of drayage. To this end, a model of a tractor and trailer delivery, repositioning, and pickup system that would capture the nature of the drayage operation closely was developed. The model was applied to a real-world case study of drayage to evaluate the cost savings and service improvements possible from a centralized operation. The model was structured as an integer linear program with time windows and service constraints. The general model statement is as follows: Minimize total costs of tractor and trailer activities subject to

- Service quality constraints for deliveries of loads to consignees,
- Service quality constraints for pickups of loads from shippers,
- Tractor flow conservation constraints,
- Trailer flow conservation constraints, and
- Nonnegativity and integrality constraints.

Of primary concern in this paper are the results in terms of pricing drayage services. The model formulation itself is described in detail elsewhere (*2,3*).

CASE STUDY

The case study was based on the trailer movements in the area of the Conrail intermodal terminal at Morrisville, Pennsylvania, during the 8-day period February 26 to March 5, 1989. It was found that 330 trailer loads were available to be moved between the terminal and the consignees or shippers. The traffic was highly imbalanced—215 loaded trailers arrived by rail to be delivered, whereas only 115 loads were to be picked up from the shippers and delivered to the terminal for outbound movement by rail. This imbalance is not atypical for Conrail or any northeast railroad operation. Shippers and consignees, shown in Figure 1, were grouped together into 14 areas according to their zip codes. The scheme for grouping the zip codes into the areas is given in Table 1. The trailer volume and day they were available to be moved are also

TABLE 1 Temporal Distribution of Demand for Deliveries and Pickups of Loads (Shown in Parentheses) at Areas

Area (with ZIP CODES)	Day 1	2	3	4	5	6	7	8	Empty Trailer
A 18834, 18951	1 (2)	1 (-)		- (1)	2 (-)		1 (-)		8
B 19020, 19007 19067, 19147,19135, 19047, 18974	25 (7)	5 (6)	14 (7)	10 (4)	16 (3)	5 (3)	- (4)	- (1)	84
D -- 19104	16(4)	8 (6)	4 (3)	5 (2)	6 (2)	6 (3)	- (1)	2 (2)	27
F -- 19148	3 (3)	3 (3)	5 (3)	5 (2)	7 (-)	2 (1)	2 (2)	- (1)	15
G 19562, 18105, 18071, 18085	4 (1)		3 (1)	- (2)	2 (-)	- (1)		- (1)	8
H 19063, 19567	1 (-)				2 (-)	1(-)			0
I 19481,19464, 19456			- (1)	1 (-)	2 (-)	1 (-)			0
J 07114,07032,07512	- (1)	- (2)	- (1)	1 (1)	1 (1)	- (1)			6
K 08360		1 (-)		5 (-)	1 (-)				1
L 08890,08822, 08807	1 (2)	- (1)	- (1)						2
M 19056, 19348	2 (1)			1 (-)		- (2)	1 (-)	- (1)	2
N 18346,18466,18360 18372, 18201	10 (2)	1 (2)	2 (1)	- (1)	3 (2)		1 (1)	1 (1)	13
O -- 18501	1 (-)		1 (-)		- (1)		1 (-)		1
P -- 18848	2 (2)	1 (-)	2 (1)	(1)	3 (1)	- (1)		1 (-)	8

given in Table 1. Within centralized drayage operations planning various forms of payments of draymen were considered. The results herein are based on a piecework payment plan, which means that a drayman would be paid separately for each movement of a trailer—empty or loaded—on an origin-to-destination–specific or mileage basis. The payments were derived from the current pricing guides of draymen in the Morrisville area using regression (*2*). The payments are linear functions of the distance between the terminal and the areas. The payments for loaded trailers are higher because they take into account the additional time associated with handling them (paperwork, bill of lading inspection, etc.).

Given the piecework drayage rates (cost) for each alternative and traffic data, the model produced an optimal operations plan with integer flows of tractors and trailers that minimized the cost of moving the loaded trailers and distributing empty trailers for loading on return movement, while satisfying the customer's schedules for pickup and deliveries. Considering the simplifications necessary in any modeling, some weaknesses in the demand data, and assumptions necessary because of data limitations, it was concluded that a 40 percent reduction in cost was a reasonable target for savings resulting from optimized operations planning. The actual results, discussed in detail elsewhere (*1*), specified somewhat larger savings depending on assumptions and payment plans.

MARGINAL COSTS

Besides estimating the overall cost, the model yields the marginal or incremental cost of an additional drayage movement. This is computed by considering the change in total cost resulting from moving an additional load. The marginal costs would in general differ considerably from the direct cost that could be associated with the loaded move (if any, as argued before).

The marginal costs are used for two purposes. One is to examine their stability spatially and over time, important features if they are to be used as a basis (along with others) for pricing. The other is to compare the incremental costs of loaded trailer movements with two rates: current drayage rates and the piecework costs for single moves derived from the current rates. The rationale for this is to ascertain the extent to which current or piecework pricing would reflect marginal costs.

Calculation of Incremental Costs of Moving Trailer Loads

The drayage model, when solved as a linear program, yields shadow (dual) prices associated with constraints on the delivery and pickup of trailer loads. The shadow price represents a change in the total cost of operation resulting from moving an additional trailer load, within a time window, between the terminal and a particular consignee/shipper. These model-generated shadow prices are used to approximate the true incremental costs of moving trailer loads.

The shadow prices and thus marginal costs are calculated in two ways. One is to solve the continuous-variable version of the model to optimality, thus yielding the marginal costs associated with the real-valued tractor-trailer flows. These costs are given in Columns 2 and 3 of Table 2. The real-valued flows mean that, in the model, an additional trailer may be moved in fractional amounts (e.g., 0.3 of a single trailer may be moved on one day and 0.7 on the next day). Of course such moves are not physically possible. The second way is to solve the model to yield marginal costs associated with integer-valued tractor and trailer flows. However, these integer flows were not necessarily optimal, as noted by Spasovic (*2*). The marginal costs associated with the integer-valued flows are given in Columns 4 and 5 of Table 2.

Table 2 indicates that the marginal costs associated with the real-valued flows vary considerably with the time when the load is available for movement. In Area K, which receives seven loads from the terminal and sends zero, accepting a delivery of an additional load from the terminal in either Day 1, 6, 7, or 8 would increase the total cost of the operation by \$118. Accepting the load on Day 2, 3, 4, or 5, however, would increase the cost of operation by \$202. In the reverse direction, though, the pickup of an additional load at K on any day of the study period would increase the cost of operation by only \$18. The last two columns of Table 2 indicate that the marginal cost of delivering an additional integer-valued load from the terminal to Area K is \$202, whereas the cost of picking up a load is \$18. Note that the marginal costs associated with the integer flows do not vary with the time the trailer load is available for delivery or pickup.

The comparison of marginal costs associated with real- and integer-valued flows is shown in Figure 2. The marginal costs associated with real-valued tractor-trailer flows are plotted against the marginal cost associated with integer-valued tractor-trailer flows. The square symbols along the 45-degree line in the graph represent identical values of marginal costs for moving loads to and from consignee/shipper areas. The triangle symbols show the values of costs that are different; the magnitude of this difference can be measured by the triangle's distance from the 45-degree line. Since marginal costs are almost equal, and considering the fact that in the real world the movements of tractors and trailers are integer valued, only the marginal costs associated with integer flows of tractors and trailers are used in further analysis.

When marginal costs are used for pricing, an important feature is whether they yield revenue sufficient to cover the cost of the drayage operation. It is of course typical in a transportation context for there to be economies of scale and density and for prices set at marginal costs to yield total revenue less than total cost. In the case where marginal costs are greater than average costs, if the drayage were priced at marginal costs, total revenue would be sufficient to cover the cost.

There are economies of scale and density in this linear model of drayage operations. For example, if the traffic volume is halved, the cost of operation would not necessarily decrease by 50 percent. Because of the systemwide impacts, opportunities for combining movements to reduce inefficiencies (e.g., deadheading and bobtailing) may be lost.

Pattern of Marginal Costs

The pattern of marginal costs presented in Table 2 reveals many interesting features. First, the cost of moving a load in

TABLE 2 Comparison of Calculated Marginal Costs of Deliveries and Pickups of Loads

Area	Marginal Costs[1] ($) of		Marginal Costs[2] ($) of	
	Delivering Load	Picking Up Load	Delivering Load	Picking Up Load
A	146	18	146	18
B	72	18	72	18
D	128	18	128	18
F	148	18	148	18
G	233	Days 1-7 17 Day 8 57	233	17
H	Days 1-4 283 Days 5-8 293	Days 1-7 17 Day 8 29	283	17
I	Days 1-3 142 Days 4-8 185	Days 1-3 31 Days 4-8 18	180	18
J	Days 1-3 94 Days 4-5 136 Days 6-8 63	102	128	110
K	Days 1, 6-8 118 Days 2-5 202	18	202	18
L	Day 1 115 Day 2 41 Days 3-8 18	Days 1-3 39 Days 4-8 18	107	47
M	Days 1-2 187 Days 3-5 151 Days 6-8 158	Days 1-5 17 Days 6-7 43 Day 8 47	161	43
N	348	42	340	50
O	384	18	384	18
P	534	18	534	18

[1]Marginal costs are associated with the real-valued flows of tractors and trailers.

[2]Marginal costs are associated with the integer-valued flows of tractors and trailers.

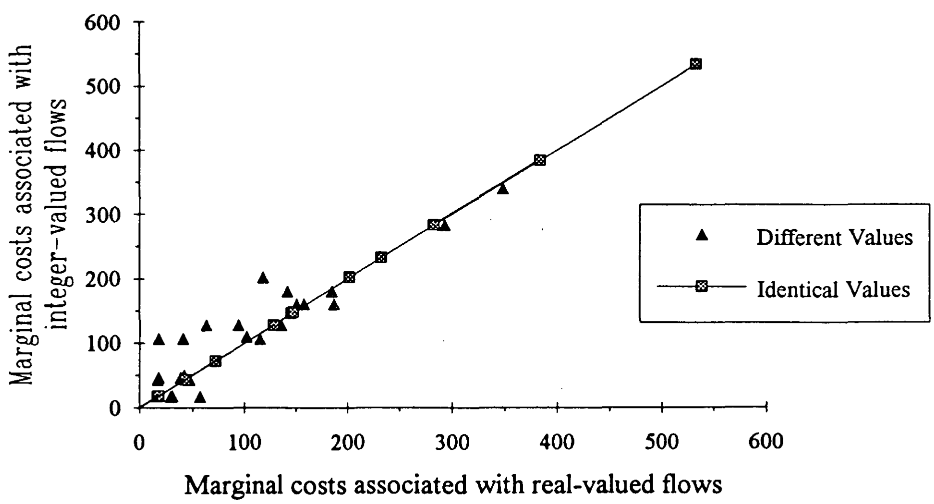

FIGURE 2 Comparison of marginal costs from integer-valued solution with those from real-valued solution.

the higher-volume direction (delivering a load from the terminal) is much higher than that of picking up a load. That there is a difference is expected, but the magnitude of the disparity is noteworthy. The average ratio of marginal costs of delivery to pickup is 9.95, reflecting the traffic imbalance.

The expected pattern of cost increasing with distance is also evident for deliveries but not for pickups, as shown in Figure 3. Increases in cost with distance for deliveries can be explained by the fact that each additional delivery generally requires an additional tractor round-trip. But many pickups can be moved by a returning tractor and empty trailer, and thus the additional cost is simply the added time for loading and added mileage for repositioning. The variations in pickup cost are explained primarily by the variability in added mileage.

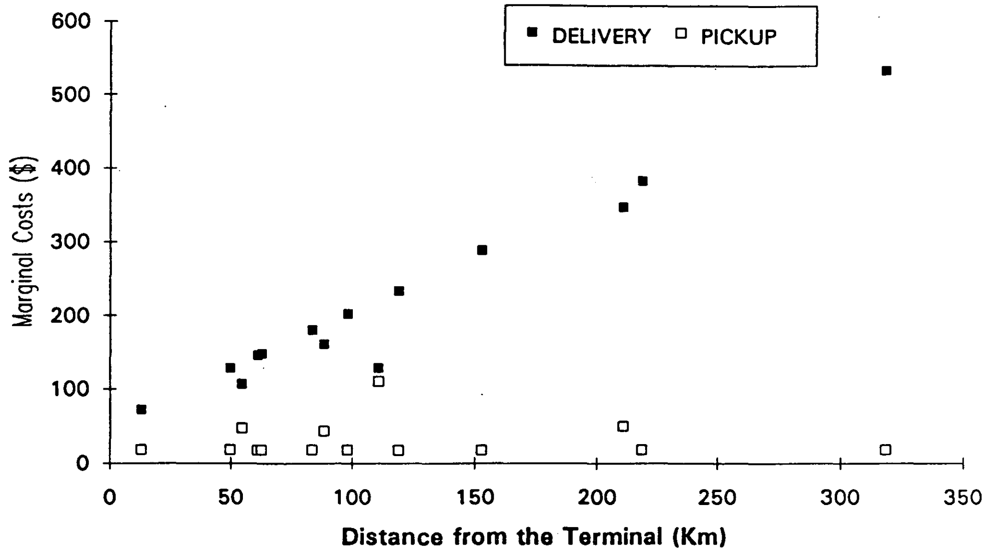

FIGURE 3 Marginal costs for pickups and deliveries versus distance from the terminal.

Evaluation of Current Rates

The comparison of marginal costs with rates for drayage in the current operation is given in Table 3. The marginal costs of delivering loads are always smaller than the current rates. On the average, the marginal costs are 73 percent of the current rates, with all values being in the 40 to 93 percent range. These values indicate that there is room for reduction in the current rates. The current rates for loads to Areas A, B, D, G, H, I, O, and P are approximately $50 larger than their respective marginal costs. These differences represent the cost of 2-hr tractor idling at the areas at $25/hr. This implies that tractors moved to and from these areas in the drop-and-pick operation. The reason is that there is sufficient two-way traffic so that tractors can be engaged in productive work (i.e., they can leave trailers at the areas and depart to new assignments) rather than having to wait while the trailers are loaded or unloaded. Thus, from Table 3 and the above analysis, it can be concluded that the current rates can be reduced on the basis of the criterion of revenue covering costs.

TABLE 3 Comparison of Current Drayage Rates and Marginal Costs

Area	Stay-With Current Rate ($) for Loaded Trailers	Marginal Costs[1] ($) of Delivering Load	Marginal Costs[1] ($) of Picking Up Load
A	195	146	18
B	123	72	18
D	179	128	18
F	198	148	18
G	283	233	17
H	334	283	17
I	230	180	18
J	271	128	110
K	251	202	18
L	268	107	47
M	237	161	43
N	421	340	50
O	434	384	18
P	484	534	18
Ratio of Marginal Costs to Stay-With Rates for Loads			
Average		0.73	0.12
Range		0.4-0.93	0.03-0.41

[1]Marginal costs are associated with the integer flows of tractors and trailers.

The marginal costs of picking up loads at Areas A, B, D, F, G, H, I, O, and P are significantly smaller than the current rates. They are, on the average, 12 percent of the current rates with actual cost for all areas being in the range of 3 to 41 percent. An issue in setting prices is of course that for any firm to remain in business its total revenue must at least equal its total cost. The cost of the centralized operation is about $ 38,300, 60 percent of the current cost. Using the marginal costs in Table 4 as the prices for all movements yields a total revenue of $37,834, only about 1 percent less than the cost. Thus prices would have to be set 1 percent higher than the marginal costs, on the average. However, this is still much below the level of current prices. Again, we can conclude that the current drayage rates could be significantly reduced.

These conclusions about possible reductions in the current rates must be viewed in the context of assuming that all trailers are moved according to a unified plan for the entire terminal area. As stated earlier, in the current operation the draymen and intermodal retailers lack the comprehensive information on trailer movements necessary to achieve such a system-optimal operation.

Evaluation of Piecework Costs

The comparison of marginal costs and piecework cost for moving trailers in a centralized operation is given in Table 4. The marginal cost of delivering a load from the terminal to Areas A, B, D, E, F, G, H, I, K, O, and P is, on the average, 1.71 times higher than the one-way piecework cost. For these areas, a marginal cost equals the sum of piecework rates for loaded and empty trailer terminal-area movements. Looking, for example, at Area K, the marginal cost of delivering a load from the terminal, $202, represents the sum of piecework costs

TABLE 4 Comparison of Piecework Rates and Marginal Costs

Area	Piece-Work Rate ($) for Delivery or Pick Up of		Marginal Costs[1] ($) of	
	Loaded Trailer	Empty Trailer	Delivering Load	Picking Up Load
A	82	64	146	18
B	45	27	72	18
D	73	55	128	18
F	83	65	148	18
G	125	108	233	17
H	150	133	283	17
I	99	81	180	18
J	119	102	128	110
K	110	92	202	18
L	77	59	107	47
M	102	85	161	43
N	195	177	340	50
O	201	183	384	18
P	276	258	534	18
Ratio of Marginal Costs to Piece-Work Rates for Loads				
Average			1.71	0.28
Range			1.08-1.93	0.07-0.92

[1]Marginal costs are associated with the integer flows of tractors and trailers.

for loaded and empty movements between the terminal and the area (i.e., $110 plus $92). This finding implies that, because of the present traffic imbalance, an additional trailer delivered from the terminal cannot be reloaded or advantageously repositioned to a new area and loaded and thus must be returned empty. Therefore, for the delivery of loads to these areas, the shipper should be charged a drayage rate that is at least equal to the marginal cost. Otherwise, this load is moved at a loss, and the load should be rejected. To summarize, it is clear that directional imbalance and volume of traffic are the major factors affecting the magnitude of marginal costs.

The marginal cost of picking up a load at Areas A, B, D, E, F, G, H, I, K, O, and P is on the average 28 percent of a one-way piecework cost for loaded trailers. The railroad should take advantage of this low marginal cost and solicit loads from these areas and balance the flows in order to increase its market share and in the long run the profitability of service.

Currently, it is common practice for the intermodal retailers to ask for reduced rates at which to sell the movement of trailers in the westbound (or light traffic) direction. However, despite the general traffic imbalance, for some of the areas (e.g., Areas J and L), the traffic is heavier in the westbound direction, and thus these areas will have a higher marginal cost for pickup. This marginal cost should be considered in determining the drayage rates for trailer movements and, thus, the door-to-door rate in the westbound direction. The use of marginal costs will eliminate the current practice of granting a lower rate for door-to-door movements that have costly drayage.

The general conclusion from this analysis is that the piecework costs (rates) of draymen are definitely not a proper basis for deriving drayage charges to shippers. The marginal costs vary too much by direction and location, being more than drayman rates in some instances and far less in others. This means that in general some sort of overall drayage system model that can determine marginal costs will be essential for economically sound pricing of the drayage component of intermodal service. This is true even if rates are set above the marginal cost.

CONCLUSIONS

The primary conclusions from this research are as follows:

1. In the system studied, current drayage rates bear no resemblance to the cost of moving trailers in an optimized system. In general, they are higher than needed to either cover marginal costs or yield revenues greater than overall costs, but by widely varying amounts depending on the customer location and direction of haul. Whether prices should differ as much as marginal costs depending on direction depends on competitive conditions that were not addressed in this research.
2. Charges of draymen for the individual moves involved in handling a trailer are also a poor guide to the marginal costs of accommodating loads for pickup or delivery.
3. Therefore, a systematic procedure for determining the incremental costs of handling each trailer is necessary. Whereas any model that incorporates an assignment of tractors to loaded trailers and supporting empty trailer movements would provide a basis for calculating these costs, a model that optimizes this assignment (and movements) to meet service requirements at minimum cost has obvious advantages. Given that such a model exists, in research prototype form, it is a natural basis on which to develop a daily operations support and costing model.
4. If centralized operations planning were introduced and drayage prices varied primarily by direction and location rather than by mileage or time required for the movement, payments to draymen could not be based on those prices (because they would not in general yield, for any arbitrary set of moves, overall revenue greater than overall cost). Therefore a means of paying draymen that meets tests of revenue adequacy and

fairness would have to be developed. In principle, this is not difficult, but in practice it may be.

5. Given that current drayage prices found in the case study are generally higher than the incremental costs of drayage and that total current expenditures for drayage are much higher than those of an optimized system—even after allowing for inevitable cost escalation from the model estimates—the cost of the drayage component of intermodal door-to-door prices can be reduced substantially. Thus intermodal carriers could reduce the door-to-door rates for the service, increasing its competitiveness with over-the-road trucking, and also retain some of the cost savings as added profit. This would help to overcome the widely reported low profitability of intermodal to the rail carriers in many markets.

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