APPROACHES FOR IMPROVING DRAYAGE IN RAIL-TRUCK INTERMODAL SERVICE

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APPROACHES FOR IMPROVING DRAYAGE IN RAIL-TRUCK INTERMODAL SERVICE

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Abstract
Approaches for improving service quality and reducing cost in the highway portion of rail-truck intermodal transportation are discussed. The highway portion -- termed drayage -- is a major source of service inferiority to the primary competitor -- over-the-road trucking. Drayage costs are also very high, and because these do not vary with the length of the intermodal haul, they preclude profitable intermodal service in the shorter domestic freight markets of less than 600 miles where the highest truck volumes are found. In addition, the inferior service quality precludes intermodal from competing for high quality premium traffic. The potential for overcoming these disadvantages through reorganization of the drayage operation and use of centralized drayage operations planning is discussed. Specific changes in the organizational structure of intermodal and in its operating procedures are outlined.

1 INTRODUCTION

The purpose of this paper is to identify and discuss approaches for improving service quality and cost of domestic intermodal service. In intermodal transport in general, a load is moved between the origin and the destination in the same container in a coordinated manner using two or more transportation modes. The specific system of concern in this paper is that used in conjunction with rail-truck intermodal or piggyback service in the United States. In piggyback service, highway trailers or containers loaded on rail flat cars are hauled by train in line-haul service between the origin and the destination intermodal terminals, and locally picked up and delivered by truck between the terminals and shippers and terminals and receivers (termed consignees).

As will be discussed below, rail-truck intermodal service suffers from serious problems in both productivity and service quality, in drayage or trucking portion of this

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service. This poor productivity effectively limits intermodal to longer distance hauls -- generally greater than 600 miles, thus precluding it from capturing the higher volume shorter-haul domestic merchandise traffic markets. Without quality improvements, major inroads into these markets currently held comfortably by over-the-road trucking will be impossible. After providing the reader with a background on intermodal and its potential, and identifying problems in the drayage operation, approaches for improvements in drayage productivity, with implications for service quality and cost, are described.

2 BACKGROUND

2.1 The Rail-Truck Intermodal Concept

The basic concept of intermodal rail-truck service is as follows. Either truck trailers or containers can be the basic intermodal units; the case of trailers will be described first. A tractor with an empty trailer (or container) would be dispatched from the intermodal terminal to a shipper's location in order to pick up a load. The tractor and driver could wait with the trailer while it is being loaded, in which case the loaded trailer would then be returned to the intermodal yard for the rail movement. This procedure is termed "stay with". Alternatively, the trailer might be left with the shipper for loading at a later time, the tractor then returning without the trailer to the intermodal terminal yard. After the trailer has been loaded, a tractor would be dispatched to pick up the trailer and return it to the terminal. This latter option is called "drop and pick". At the terminal, the loaded trailer would be placed on a piggyback car which would be then hauled in a train to the destination area intermodal terminal. At the destination end, the drayage operations would commence, with the trailer delivered to the consignee. After unloading, the empty trailer would be returned to a pool of empty trailers at the intermodal terminal. The destination drayage could use either the "stay with" or the "drop and pick" procedure.

In the case of containers, the operations are similar, except that only the container is carried on the rail car. As a result, a bogie or chassis must be provided for all road
Organizational, intermodal has been provided in a number of ways, including railroads providing the four key aspects: rail line haul, terminals and their operation, sales, and the drayage, all with rail owned equipment and empties. In the last couple of decades, intermodal service to all but the largest shippers (notably UPS and US Postal Service) is being accomplished with independent truckers providing the drayage, and independent sales agents termed intermodal marketing companies (IMCs) doing the selling. The result is shown in Figure 2, with the IMCs arranging for rail line haul and drayage.

2.2 Economies of Intermodal Transport

Rail-truck intermodal was primarily designed to compete with over-the-road trucking. In principle, it combines the best of two modes; economies of rail line haul wherein a large number of trailers (or containers) is moved at a lower average cost compared to the parallel over-the-highway movement, with flexibility of truck in local drayage -- this flexibility enabling pick-up or delivery at the customer's convenience rather than when a local freight train happens by, and enabling service to points not on rail lines, among other advantages. The cost characteristics of intermodal service and trucking are quite different, as illustrated in Figure 1, which portrays the full (or long run) cost of the two modes on a pre shipment basis as a function of distance. In the case of trucking, there is a small fixed or threshold cost that is independent of distance, representing the cost of transactions associated with the movement (documentation, billing, etc.) and of the loading and unloading activity (including truck time, etc.). The cost of operating a truck (including ownership, maintenance, etc.) is essentially proportional to distance. Typical values for the threshold cost are about $80 to $120 per load and the cost per unit distance is typically in the vicinity of $1 to $1.50 per loaded load.
truck-mile, assuming that about 80% or more of the total miles are loaded which is typical of the most efficient truckers. These costs could be increased proportionally to include the effect of greater empty mileage. Intermodal transport incurs a much higher threshold cost, including, in addition to the transaction and loading costs, the costs of providing the terminal facility, of loading the trailer on the rail car, the corresponding unloading operation, and of drayage at each end. Typical values for the threshold cost are $300 to $500. The rail line haul cost per unit distance is in the vicinity of $0.60 to $0.80 per trailer mile.

The net effect of the different cost structures is that there is a break-even distance below which trucking is less costly and above which intermodal is less costly, as indicated in Figure 1. Generally this is thought to be in the vicinity of 500 to 700 miles. Of course, local conditions, particularly the extent of adverse distance for drayage (i.e. drayage opposite to the direction of the destination), and the degree to which equipment is fully utilized in both directions, will influence the break-even distance. Using mid-range values for the above costs of over-the-road and intermodal movements results in a break-even distance of 546 miles.

While the preceding discussion has been in terms of the carrier cost, it is also important to consider the cost as perceived by the shipper. The shipper not only pays the carrier directly for the transportation service, but in addition incurs other costs associated with the movement. These include the cost of the cargo inventory while in transit, inventory used as a safety stock in case expected deliveries are late, other inventory costs, packaging costs, and possibly production or distribution costs. These costs vary with the mode, because of differences in travel time, reliability, ride quality, and other level of service (LOS) factors. While the effect of these other factors varies greatly among different commodities and particular situations, these almost always increase the break-even distance between rail and truck. This break-even distance is usually thought to be in the vicinity of 700 to 1000 miles. Using the costs of over-the-road and intermodal
movements, and including a penalty of 15% added to the intermodal carrier's costs to adjust for the service inferiority, results in a break-even distance of 809 miles. This 15% penalty is often cited as being representative of the value of service inferiority (I, p. 52). For a haul of $d$, the truck cost would be $100 + $1.25d$ while the intermodal cost would be $1.15 ($400 + $0.70d$). Equating and solving for $d$ yields $d = (1.15*(400 - 100))/(1.25 - 1.15*0.70) = 809$ miles. This value is within the range of a break-even distance indicated earlier.

It should be noted that intermodal was envisioned to be competitive with intercity trucking in the sense that it would offer a similar service at a lower cost. However, the actual cost structure and inferior service quality result in a high break-even distance. This precludes intermodal service from being a competitive alternative to truck in short haul markets for which it was originally intended. Given that over 75% of all cargo moves over distances of 500 miles or less, and 90% moves 900 miles and less (2), intermodal's competitive position is thus limited to a rather small segment of the intercity freight market.

In addition, although intermodal traffic volume has grown rapidly over the past decade, many analysts have concluded that intermodal has been and still is characterized by low profit margins, describing it as "a great revenue business but poor net revenue business" (3). It is argued that the low profit margins do not yield acceptable returns on investment and in turn do not justify the railroads' further investments in intermodal equipment. This is especially noteworthy because intermodal traffic is concentrated in long haul markets where its cost advantage over trucking is the greatest, as shown in Figure 1, and hence the potential for high-margin pricing is the greatest. This weakness in profitability would explain the lack of investment that has resulted in a serious equipment shortage and terminal capacity problem, documented in (21), for example, that is threatening to slow the intermodal growth. In addition, the intermodal was unsuccessful in making inroads into shorter haul markets of high value merchandise freight.
3 POTENTIAL OF INTERMODAL

In the last decade, intermodal service as a whole has grown by a factor of over 100%, i.e. from 3.06 million units in 1980 to 6.21 million units in 1990 (4). Various indicators suggest that the growth in intermodal is going to continue. A number of factors have supported this trend and these and others suggest that it is likely to continue.

One of the most significant factors supporting this is the shortage of qualified truck drivers. This shortage is primarily caused by the growing reluctance on part of the current drivers to continue in the profession that requires them to spend weeks away from home, lack of interest among the eligible drivers in entering the profession, and to some degree drivers failing physical exams due to substance abuse. In addition, the driver shortages are further aggravated by traffic imbalances that leave drivers stranded for days in one location waiting for the return loads, if the loads can be found, for example, the excess loads from the production regions of the Mid-West to the consumer regions in the Northeast.

Faced with driver shortages and low rail intermodal rates, several long distance truck-load (TL) motor carriers have made alliances with railroads to whom they contracted out the intercity portion of the truck line haul (5). The truckers have found that it is cost effective to keep their drayage operations at the intermodal terminals in major market areas, with drivers stationed there, and utilize a reliable rail link between the markets. While the contracting out of the line haul could undoubtedly yield significant cost savings, the resulting predictability of work load and local nature of driver work assignments should improve driver retention as well. The positive experiences of less-

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3 Unfortunately, data on domestic intermodal trailer-on-flat-car (TOFC) and container-on-flat-car (COFC) services as a whole are not available, as these services are typically grouped with the carriage of international containers which are forwarded by rail to and from inland locations for a subsequent trip by water.
than-truck-load (LTL) and some TL carriers in using intermodal, the continuing driver shortages, and recent liberalization of union agreement restrictions on LTL carriers using intermodal, all point to further increases in the volume of intermodal traffic.

The second major force behind the continued expansion of domestic intermodal is domestic containerization. In the early 1980s, domestic containerization was spurred by the re-loading of steamship line containers, which came from the Pacific Rim countries carrying import cargo to the US ports on the West Cost and moved inland by rail. Domestic freight was obtained to fill otherwise empty back-hauls to the west (6). The cost advantage resulting from moving containers double-stacked on flat rail cars, thus decreasing the average cost of the line haul, and a good performance of the service with respect to the damage, led to an increase in volume of domestic containers. As a result of cost advantages and shipper's perception of double-stack as a high quality service, numerous trucking and shipping companies begun investing in a domestic container fleet (7).

Third, the public's attitude toward large trucks is changing. Articles decrying the subsidization of heavy vehicles on the Nation's highways with respect to road maintenance costs are increasingly common, as are articles pointing out the hidden subsidies to road traffic in general. As a result, higher user fees, especially for heavy vehicles, are likely. The introduction of new IVHS - technologies for automatic vehicle identification (AVI), classification (AVC), and weight-in-motion (WIM) will facilitate the introduction of user fees that are distance and weight based. Obviously, the truckers are the natural target for those fees. Also, public opinion seems to be against liberalization of vehicle size and weight increases, as illustrated by the last federal action on this subject.

Finally, it is widely perceived that society would benefit from a diversion of freight traffic from highway to improved rail intermodal. The potential benefits of such a shift could be incurred in the areas of highway safety, better allocation of funds for
highways, and environmental protection. The shift in traffic could reduce the number of tractor-trailers on the highway, thus potentially increasing the safety of passenger transportation and reducing the congestion. The decrease in volume of intercity highway traffic would reduce the damage of highways and, thus, decrease repair and maintenance cost. Last, but not least, intermodal is being perceived as an environmentally correct or "green" mode of transportation which is more fuel efficient than truck (e.g., rail can move the given quantity of freight at less fuel), and thus, it could reduce the air pollution as well as the consumption of fossil fuel. Recent governmental promotion of intermodalism, brought forth by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1990, calls for the development of innovative ways for planning and financing of intermodal services. This could further stimulate intermodal growth.

The increased use of intermodal by truckers in the last two years attests to the general trends of its continued expansion. All indicators show that truckers will be in the intermodal business for the foreseeable future. A recent study designed to ascertain preferences about intermodal among the intermodal users and non-users indicated that 80% of shippers surveyed expected TL truckers to offer intermodal services in the next three to five years (7). It seems that an early concern that the growth rate of piggyback use among truckers may be limited by the availability of suitable trailers, since not all existing equipment is suitable for piggyback operation, is being eased with more and more truckers buying their own container fleets. For example, J. B. Hunt had been invested 56 million dollars in new containers that will be used exclusively in intermodal. The major driving force behind this are intermodal revenues which in 1993 were twice those of 1991. In 1995, Hunt expects intermodal to represent half of the company's business (8). Its 110 inch high, 45 foot long containers are 4 inch higher than the ordinary railroad, steamship or third party leaser-owned containers, and can carry up to 1,000 pounds more. In fact, the Hunt containers have the same capacity as ordinary over-the-highway trailers.
It should be noted that, unlike railroads, J. B. Hunt and other truckers seem to have been able to get a satisfactory return on their investment from dedicated intermodal fleets and are continuing with equipment acquisitions. Their traffic now represents a significant portion of the growth of railroad intermodal traffic; fully 50% of last year's growth came from private fleets (9). All this indicates that intermodal as a transportation service is sound and likely to grow. But the question remains as to the extent to which railroads and their traditional parties in intermodal - IMCs and drayage companies - will participate in and benefit from this growth. This question is discussed next.

4 DRAYAGE AS SOURCE OF PROBLEMS

Despite the recent growth of intermodal, there is ample evidence that there is considerable need for improvement if it is to capture a much larger share of freight. At present, it has been estimated that intermodal carries approximately 10%-15% of the intercity merchandise cargo that is moving at distances over 500 miles (6,10). This implies that its market share is very small in the high value cargo market for which it was intended. As it will be discussed below, intermodal rail-truck service suffers from serious problems in both cost (price) and service quality.

There are numerous reasons for this that have been revealed by many recent studies probing shippers' views of intermodal. All seem to point to essentially the same features. Table 1 presents the summary of results of one such study (11). The table reports the percentage of shippers surveyed who cite each of the eleven reasons why they currently do not use intermodal. The most commonly cited reason is that intermodal transit time is not competitive with truck. This is not surprising given the typical intermodal service of one train per day in each direction (although over a longer distances the higher cruise speed potential of rail could and sometimes does overcome this time disadvantage.
Another factor underlying this is the fragmentation of responsibility and control for intermodal movements. Compounding the effect of the fragmentation are the significant delays which are common between the time when the trailer/container arrives at the destination terminal and when it is picked up by the draymen for delivery. The next most frequently cited reason is that the service is not available. This reflects both the limited number of points between which intermodal service is operated and its absence from most shorter distance markets (again, defined here as less than 500 miles) in which the majority of truck traffic moves.

Interestingly, the third most frequently cited reason was the fragmented responsibility for the service. The difficulty associated with damage and loss problems was also cited, but less frequently. While fragmented responsibility is separately cited, it clearly is a major factor underlying items numbered 6 through 9 and items number 2 and 11 in the survey. Cited by about a quarter of the shippers were undesirable equipment and unreliable equipment. This undoubtedly is partly due to many railroads' reluctance to invest in intermodal as described earlier. Also, there is much uncertainty as to what particular equipment technologies will be desirable and needed in the future, a reflection of the fast pace of technological change. Interestingly about one fifth of the shippers indicated that the price of intermodal was too high. One interpretation of this is, of course, that the service disadvantages often found in intermodal are not sufficiently offset by price savings relative to trucking.

A more recent study (10), the results of which are reported in (12) and shown in Table 2, addressed shippers perception of intermodal by asking both users and non-users (of intermodal) the following two questions: How likely were you to increase the use of intermodal if certain improvements in service quality were made?, and How much are you willing to pay for these improvements?. The results of the survey reveal that 70% of the current users of intermodal surveyed would increase its use if loads are delivered the day when they are scheduled for delivery. Almost 60% of the shippers are also willing to
pay more for the service with guaranteed delivery and with a penalty for non-performance.

Finally, a study of a typical intermodal terminal operation (13) on a major US railroad revealed that drayage -- and related terminal activities -- is clearly the weak link in intermodal service. While very stringent service standards were applied to the rail move, essentially none were applied to drayage. A survey of actual drayage operations, at what the management felt was a typical terminal, revealed that trailers inbound by rail remained at the terminal awaiting delivery for an average of 2.3 days, with a standard deviation of 1.8 days. Only 33% of inbound trailers were removed from the terminal for delivery within 24 hours of arrival and 98% were dispatched within four days. Delivery to the consignee would normally be within a few hours of dispatching, given the distances involved. No similar data were available on pick-ups, but interviews with drayage companies revealed that most pick-ups were arranged one or more days in advance. A comparison of these indicators with the "premium" intermodal service provided to UPS and US Postal Service at the same terminal, where truck and rail movements are closely coordinated and drayage performed by a dedicated trucker, revealed that the delivery times are shorter than currently achieved in domestic intermodal. The time between trailer arrival on rail and delivery by truck was on average 1.7 days, with a standard deviation of 1.6 days.

The above problems are either caused or directly relate to the inefficiencies in drayage operation. Unless drayage productivity is improved, the intermodal service will be limited to longer distance hauls and thus precluded from the higher volume medium-haul domestic merchandise freight markets. Without quality improvement, major inroads into the premium freight markets currently comfortably held by over-the-road trucking will be impossible.

4.1 Past Improvements in Intermodal Service
In order to compete more effectively with long haul motor carriers, a number of significant changes have been made in intermodal service in the last two decades. First, there has been a major change in the technology of rail equipment and track structure. The introduction of articulated cars (i.e. adjacent cars that are semi-permanently coupled together and share a common wheel assembly) reduced the slack between the cars, thus reducing the source of jerking and banging and hence of cargo damage in train movement. In addition, the reduced tare (empty) weight to load ratio and complexity of the units, together with the improved aerodynamic properties, resulted in improved fuel consumption and reduced fuel and motive power (locomotive) requirements. These changes reduced the cost of the rail line haul movement. The new lighter equipment is also less expensive to purchase and maintain, thus resulting in reduced track wear and maintenance costs.

A second major change has been to concentrate traffic at fewer terminals between which dedicated intermodal trains are operated. Between 1978 and 1986, while the intermodal volume grew by 88%, the number of intermodal terminals decreased from 1,176 to 361 (14). This densification of traffic has led to economies in terminal operation by enabling more highly automated equipment to be used. But a major shortcoming of this consolidation and use of hub and spoke operation is of course that, while it decreased the terminal costs throughout the system, it also caused the average length of drayage to increase. This has resulted in a higher average cost of drayage. Also, the use of dedicated trains has reduced the transit time of cars between terminals, primarily because these trains make few if any intermediate stops. This has also reduced loss and damage to cargo since cars need not to go through the classification yards commonly used by regular freight trains. The use of dedicated trains has also facilitated their operation on a strict schedule, thus improving both the overall travel time characteristics of intermodal and its reliability -- at least on the rail portion.
A third important change has been that almost all railroads have turned over a sizable portion of the sales or retailing effort for intermodal to third parties, termed intermodal marketing companies (IMCs), who act as brokers in arranging for movements. Primary motivations for this were to obtain nation-wide sales forces and also to obtain marketing services that were more responsive to shippers' needs.

A fourth change has been to reduce labor cost. Line haul labor cost has been decreased by decreasing the train crew size, in most cases from three to two. Also, costs of some of the very labor intensive portions of intermodal service were decreased by outsourcing or contracting, including terminal operation and maintenance. The other service that was outsourced was that of the drayage, and this is now largely done by relatively small competitive trucking firms whose costs are considerably below the historic cost levels of railroad trucking (drayage) subsidiaries.

These changes in sales and drayage have resulted in a relationship between the railroad and the shipper which is at least one step removed, as shown in Figure 3. While it has undoubtedly reduced the cost of these activities, this has two distinct disadvantages. One is loss of contact with the shippers and consignees -- the customers of the service. The second is fragmentation of responsibility for providing the service, this being split between the IMCs, the draymen, and the railroads.

5 REQUIREMENTS FOR IMPROVED SERVICE

The previous section points rather clearly to drayage being the primary source of problems with service quality and cost of intermodal service. Given the reliable and fast dedicated train service, drayage is the primary cause for both long transit times and transit time unreliability. Also, drayage accounts for a very large portion of intermodal door-to-door cost, as is easily seen by considering a few examples. Assuming optimistically that drayage requires only 1 hour of tractor time at each terminal, 2 hours (up to 40 miles each way) driving (round trip) at the origin, the same at the destination, and 1 hour for loading
and the same for unloading (8 hours total), at $40/hour, leads to a $320 charge for pick up and delivery combined. Allowing $50 for the retailers and $50 for the terminal handling, and $0.70/mile for a rail line haul, yields, for a 1,000 mile haul, a total of $1,120, of which 29% is drayage. If the line haul were 1,500 miles, the drayage portion is 22% of the total costs, at 700 miles, fully 35%. Drayage as a portion of the total door-to-door cost for various lengths of rail line haul is shown in Table 3. Also, if the costs are greater than the optimistic values assumed here, or drop and pick drayage is used instead of stay with, or the line haul cost is lower, then the drayage portion is even greater. Also, one industry source indicated that drayage represented 40% of the total door-to-door cost for a 1,000 mile trip (15). Considering the improvements in cost or performance that have been made in the other major cost center (sales, terminals, and line haul) the focus naturally falls on drayage as the area for potential improvements.

The main reason for the high drayage cost is undoubtedly the high percentage of tractor and tractor-trailer non-revenue movements (called respectively bob-tailing and deadheading) that are typically required to achieve a high LOS quality of trailer pick ups and deliveries. It should be noted that drayage was envisioned from the beginning of intermodal service to be equipment and labor intensive and thus costly. It seems that drayage operations were originally envisioned as mirroring the movements of rail freight cars on local trains. Loaded trailers would be delivered, with the tractor often returning empty to the terminal for another trailer, or vice versa for load pick ups from shippers. Such operation also enabled prompt delivery and pick ups of loads.

Clearly, the prompt delivery with short time window in which the movements must be made decreases the probability that both a shipper and a consignee in the same area or in the vicinity would request service during the same time window. Thus, the opportunity of using the same truck trailer that delivered a load to the consignee, upon unloading to pick up a load from a shipper would be diminished. The drayer would have
had to charge high rates to account for substantial deadheading associated with the operation.

Another obstacle to an efficient operation could be the fragmentation of control over drayage between various players, IMCs and the draymen alike. This fragmentation leads to many unnecessary tractor movements, bob-tailing and deadheading. It is not uncommon that at the typical rail terminal, the drayage operation involves a dozen or so IMCs and two dozen drayers each controlling several load moves and scheduling their operations independently of one other. This means that tractors often move into and out of the same area, at about the same time (or within the same time window of a couple of hours) hauling loads of different IMCs in opposite directions and returning empty.

Consider for example a drayage operation shown in Figure 3. Here, a load must be delivered from the terminal to a consignee and an empty trailer must be delivered to a shipper for loading within the same time window. Upon loading, the trailer is to be returned to the terminal for the outbound movement on rail. In drayage, the cost (rate) is proportional to the miles traveled (or time). If the trailers are moved independently from one another, the total mileage is 4L. By coordinating the drayage, the mileage could be decreased to 2L + D, where D represent the repositioning distance from the consignee to the shipper. If drayage were coordinated, the same tractor that delivers a loaded trailer to the consignee, waits while it is unloaded, repositions it to a shipper in the same vicinity, and brings it back to the terminal. The savings, in terms of reduction of tractor-trailer deadheading miles from the repositioning, over the independent operation is approximately 2L. This savings is offset by the repositioning mileage, hence the cost of 2L + D. Clearly, this operation is possible only if the shipper requests a trailer similar to the one delivered to the consignee and the request for moves are made sufficiently close in time.

To conclude, fragmentation prevents an efficient operation. Current prices are set assuming that each trailer delivery is undertaken independently of other deliveries. In
practice, costs (prices) could deviate, as load density changes and economies and diseconomies appear. The natural question is: Why not take advantage of these economies of density? Increasing load density could result in decreasing non-revenue truck mileage and thus costs. For example, with coordination and information sharing, cases of two round trip movements, each loaded in only one direction, could be replaced with one round trip movement with loads in both directions. The cost of a round trip would then be assigned over the two loads, thus decreasing the cost per load by almost half compared to the independent operation.

5.1 Proposed Centralized Drayage Operation

Improving this situation is essentially a problem in, first, creating and using the right information, and second, changing the working relationship between the various actors so that the information can be acted upon. Specifically, the drayage associated with an entire terminal must be viewed as a system, and the drayage operation planned so as to meet the demands and service requirements at a minimum cost.

The basic idea, then, would be to ascertain each day the demands to be met in the form of loaded trailers to be moved, either to the terminal from shippers or from the terminal to consignees, and of empty trailers to be spotted for loading or to be removed after unloading. Tractors and drivers would be assigned to these tasks considering the totality of work to be done, so as to minimize total cost. Simultaneously the optimal movements of empty trailers, including repositioning from consignees to shippers, would be determined and tractors assigned. This would be done by bringing together data on all the demands to be met, and by applying an appropriate tractor-trailer scheduling procedure to the problem. Draymen would then follow this master plan in executing the movements.

The quality of service in this would be preserved by scheduling the moves in advance. The times of deliveries and pick ups would be negotiated, preferably at the time
of load acceptance, considering the possibilities of pairings of moves, thus reducing empty mileage. The trade off between service quality and cost would be made for each of the customers. The opportunity of possible pairings would be monitored and, as they arise, the customer would be advised of possible savings.

Research was undertaken to evaluate the use of centralized drayage operations planning to both reduce cost (and hence price) and improve service quality of drayage (15). 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 to the current decentralized drayage operation. The structure of the model is shown in Table 4. The model is described in (15). Drayage companies would be paid rates that are based on their costs. The research revealed that substantial cost savings in the range of 43-65% reduction of cost of centralized operation compared to the current operation [see (15,16,17)]. It should be noted that these cost savings are achieved with no sacrifice of service quality of drayage; indeed centralized scheduling should permit service improvements. Even allowing for sharing of the gains among the players so that each makes a larger profit, and recognizing that some projected savings may not occur because of inevitable assumptions in modeling, such gains are clearly sufficient to permit substantial reductions in the threshold cost (i.e. the cost that doesn't vary with distance in Figure 1) of intermodal service.

6 INSTITUTIONAL ISSUES AND IMPLEMENTATION

The gains described above arise from centralized drayage operations planning (CDOP) that makes use of information that now exists but that is dispersed among many independent disconnected units namely:

- the railroad, on trailer arrivals by rail
the intermodal retailers, on shipper demands for empty trailers and time commitments for pick-ups and deliveries of loaded trailers, and

- the draymen, on the timing of movements and the location of trailers in the field

To achieve the gains envisioned, all this information must be brought together and operating decisions made considering all trailer movements that must be accomplished. The question of how this can be done is now addressed.

### 6.1 Organizational Issues

There are many alternative ways which can be identified for achieving centralized drayage operations planning. The relationships envisioned between the intermodal parties are shown in Figure 4. The institutional home of the CDOP is deliberately not specified, as this could be in a variety of organizations, including (1) an independent entity, (2) a part of the railroad's intermodal organization, (3) an undertaking of a consortium of IMCs or drayman, or jointly by both, or (4) a single retailer or drayman doing it on behalf of the others. Obviously such a partnership will require a high level of compatibility of goals and ways of doing business among the parties, and a high degree of mutual trust.

It is not difficult, though it is highly unlikely, to envision the railroad controlling the operations planning of drayage. The railroad can do that directly or through a subsidiary, or an association of drayage companies to which the scheduling function is assigned. This association would collect information on load and empty movements needed, from IMCs and the railroad, develop the plan that minimizes the cost of operation, and relay to the IMCs which drayer to use for each particular movement. A prerequisite for this scheme is that all drayers operating around the terminal are admitted into a pool. A condition to be admitted into a pool is that the drayers surrender a control
of their own scheduling to the organization. This setup, arrangement of railroad control, is not likely to be established for two main reasons. First, any move by the railroads to control drayage may be perceived by IMCs as a threat to their existence. The IMCs could easily envision that confidential information, once it is shared with the associations, will become public, and, thus used by competing IMCs to take over their customers. Second, it is widely perceived by some experts that the railroads' associations with intercity long haul truckers will put enough pressure on IMCs so that they will have to improve equipment management (9).

A more likely association would be a partnership between IMCs and a railroad in managing drayage. IMCs can be motivated to participate in such a partnership and invest their resources by being rewarded in the form of more traffic or greater profits (or the threat of loosing traffic if they did not join in). This partnership could select drayage companies to work with, and undertake the information sharing and planning itself or through a contractor, perhaps an advanced drayage company. Thus many options exist. Given the numerous options, the term "coordinated", rather than "centralized", may be equally descriptive of the changes envisioned in planning and operations.

6.2 Operating Issues

Assuming than some form of partnership for purpose of centralized drayage operations planning is established, then procedures for rational compensation of drayage, equipment activity tracking, and service quality control are needed. These procedures are critical for the practicability and workability of the unified operation.

First, the basis of payment for drayage services will have to be rationalized. Presently there is considerable variation in the profitability of different drayage moves, those to some areas being highly desirable and profitable and other not so. This is due to such factors as payment essentially on a mileage basis even though costs are incurred largely on the basis of time expended, peculiarities of only partial reimbursement for tolls
and other fees that vary with the specific move, hidden or only partly compensated activities in connection with some moves (e.g., the required return trip to pick-up the trailer in the case of a "drop and pick" assignment), among others. Now, IMCs try to assign jobs so as to spread the desirable and undesirable movements among the drayage firms and drivers, mindful of seniority, cooperation shown, etc. In addition, 90% of drayage companies use owner-operators (according to informal industry estimates). Based on discussion with drayage companies, it is typical that under the current payment scheme the owner-operators receive approximately 70% of a round trip rate that involves taking a loaded trailer out and bringing it empty, or vice-versa. This payment scheme offers the owner-operators no incentive to pair trailer moves along the lines outlined in Figure 3, because they perceive the payment they would receive for the combined operation would be much less. When the drayman is instructed by an IMCs to pair or triangulate moves, it is paid a rate that is a fraction of the two round trip rates plus the cost of repositioning. Consider for example a pairing of two $400 round trip moves that does not require repositioning. For this, the drayman would receive 55% of each round trip rate, 70% of which is paid to the owner-operator. Thus, instead of receiving $560 (70% of the two $400 round trip rates) for two independent moves, the owner-operator receives only $294 (0.7*(0.55*($400+$400))). Naturally, the owner-operators expect to get paid for their time, regardless the fact it was spent unproductively from the drayage point of view. All this must be changed in order to make the concept of centralized planning of drayage operations acceptable to the three parties involved in intermodal service.

Common to all approaches proposed in Figure 4 is the development of a computerized system -- decision support tool -- to be used for efficient scheduling and pricing of drayage moves. This system, which is envisioned to aid dispatchers in day-to-day planning, scheduling and pricing of tractor and trailer movements, consists of three modules: a customer data base, a geographical information system (GIS) for displaying
transportation network as well as customer locations and vehicle activities, and a scheduler.

The database would contain data on customer profiles. These will include: the precise addresses (street, town, ZIP of customer facilities, the site specific time-windows for deliveries and pick-ups, the characteristics of loading and unloading facilities and available equipment, the customer preferences as to the type of drayage (e.g., stay with or drop and pick operation), as well as the customer preferred types and characteristics of trailers/containers). The geo-referenced portion of the customer database would be interfaced with GIS software thus enabling the graphical display of customer locations as icons. These locations, together with vehicle location and status icons would facilitate visualizations of drayage and aid in operations planning. The "point (with an arrow) and click" (on an icon) dispatcher interface with the GIS system should provide easy access to all important customer information through convenient pull-down menus. These would facilitate browsing through and retrieving of all customer specific information.

Given the shippers/consignees requests and the current location and status of truck-trailers, the scheduler would determine an efficient (or optimal) plan of deliveries of loaded trailers to consignees and pick-up of loads from shippers and assign tractors to trailers. The scheduler would also produce optimal routing and scheduling plans for each tractor. Consideration should be given to, not only movements of loads, but also to the repositioning of empties to be loaded, to meeting shippers preferences and requirements, and to assisting in negotiating with shippers and consignees regarding the precise times of deliveries, unloading and loading, and pricing. The system should be capable of taking into account requests for services in real or near-real time and be able to produce updated schedules as needed (e.g., in response to deviations from an earlier schedule). The newly received service requests will be graphically displayed on the monitor together with revisions and schedule updates. The core of the scheduler would be an optimization model that determines the tractor assignments so as to minimize the drayage cost subject
to meeting the demands and service requirements. The optimization model of drayage operation described in (15, 17) could be used as a basis for the development of such a tool.

This system must recognize clear service commitments and provide proper rates for each drayage move to be undertaken. Currently, drayage rates are derived on the basis of average costs of an independent operation with 50% empty mileage, rather than on the actual cost of a move. Often in complex intermodal transportation systems characterized by load imbalances and terminal congestion, the movement of an additional trailer may result in a substantial increase in the cost of operation (19). This cost may be significant and exceed the rate charged for the movement, or alternatively, it could add little to the overall cost. For example, repositioning a trailer upon unloading at a consignee to pick up a load at a shipper in the vicinity for subsequent return to the terminal, can be very efficient since involves fewer empty miles compared to the case of supplying an empty from the terminal. However, the repositioning and the pick up may require an excessively long period of driver-assisted loading of the trailer, for example, thus tying up a driver in an inefficient operation. Even if the drayman gets paid for the driver and tractor idle time, the compensation may not be sufficient. The system should be able to quickly check the data base, pull out customer profiles including its loading practices, that could reveal this potential problem, and proper, higher rate would be quoted.

This problem of tying up drivers and tractors in inefficient operations can be exacerbated during periods of high (peak) demand when there could be a shortage of drivers to move the loads. In this case, the system should identify proper rates for the moves and identify the loads that may be rejected. The system should be able to recognize the time varying costs of back-haul opportunities and price them accordingly. As a result, the shippers would be provided various service commitment-price trade-offs so that they can understand how much more they should pay for the service in periods of high demand compared to the lower rates that could be quoted during a lull in drayage operation.
If a centralized operation is to be introduced, and presumably along with that set the origin-destination rates for each movement, the actual cost of drayage should be the basis for paying the drayage and for the overall shipment price. The proposed model can provide the proper guidelines for pricing of moves. Clearly, the proper pricing of drayage rates in centralized - or coordinated operation - is a prerequisite for efficient operation.

7 PUSHING FOR CHANGE

The most important question in redesigning -- or reengineering -- drayage is who should lead the proposed organizational and operational change? The answer to this is rather obvious: it is in the IMCs' best interest to lead the way for the change, because they stand to gain the most from it. The increased use of piggyback by premium long haul truckers, such as J. B. Hunt and Schneider, has dramatically changed the intermodal business. With the trucker's entrance in the intermodal arena, the IMCs have encountered, almost overnight, a strong competitor with a far reaching sales force and a vast experience in efficient equipment management (5).

It only takes simple back-of-the-envelope arithmetic to show that IMCs will not be able to compete with intermodal truckers if they continue to tolerate inefficient drayage. Because of the higher density of trailer loads in intermodal markets, an efficient trucking company (e.g., J. B. Hunt) is likely to have lower cost of drayage. The higher load density increases the probability of load matching, i.e. using the same tractor-trailer to move loads in both direction between the terminal and shippers and consignees thus reducing deadheading and/or bob-tailing. This lower drayage cost could enable the trucker to offer a competitive rate on the door-to-door movement. This rate should not necessarily be lower than the one the trucker would charge for a pure over-the-highway movement. This means that the trucker can use intermodal so as to boost its profit margins by taking advantage of shippers' perception of the superior quality of truck
service, despite the fact that the load has moved by intermodal. However, the trucker could also choose to lower its door-to-door rate to take business away from IMCs.

A hypothetical example will illustrate the trucker's advantage resulting from higher load density. In the example, a weekly volume of 1,000 TLs around an intermodal terminal is split between IMCs and long haul truckers according to a 10%:90% split. This is a plausible split since various sources cite intermodal having 10% of the market above the 500 miles length of haul (6). Assume, that in each market segment, there is a dominant firm controlling 40% of the volume. This translates into 40 loads for an IMC and 360 loads for a trucker, respectively. The trucker operates efficiently with 80% of loaded miles (i.e. it matches 80% of its loads) and is considering contracting out the intercity portion to rail. Two scenarios are assumed for the IMC operation. Under Scenario 1, the loads move independently of each other, while in Scenario 2 pick ups are paired with deliveries for 50% of the loads. The lower load density of the IMC share causes that it is unlikely that more than 50% of the load moves can be paired. Assume further that an average one-way dray is 100 miles, and that the rate is $1.25 per mile, for both the trucker and an IMC hired drayer. Also, when the loads are paired, there is an average 20 mile empty repositioning. It should be noted that in the real world, an intercity trucker is likely to the lower cost per mile, than the drayer. However, since the primary objective of this exercise is to show the impact of traffic density on the cost of drayage, the trucker's and the drayer's rates are assumed to be equal. The results, shown in Table 5, indicate an average drayage costs per load for the IMC operation of $250 and $193.75 for Scenarios 1 and 2 respectively, and $160 for the trucker. The trucker's rate is 36% and 17.42% lower than the IMC rates for Scenario 1 and 2 respectively.

Assuming the IMC operates according to the more favorable Scenario 2, the reduction of drayage cost of 17.42% would translate into a substantial reduction in the door-to-door rate. For the IMC, the door-to-door rate is a sum of drayage costs, rail cost and its fee, and is expressed as $387.5/load + $0.70/rail-mile* X (miles) + $50/load (fee).
For the trucker, this rate equals to the sum of drayage and the rail rate: $320/load + $0.70/rail-mile*X (miles). For various lengths of rail haul of 600, 700, 800 and 1,000 miles, the door-to-door trucker rate is 13.7%, 12.67 %, 11.78% and 10.33 % lower than the IMC rate. If the shippers’ costs are taken into account by imposing a 15% penalty on the IMC service rate to account for the perceived inferior service quality, the door-to-door trucker rate becomes 24.95%, 24.06%, 23.29% and 22.03% lower. The bottom line is that the trucker has a tremendous competitive advantage in terms of cost and service.

The IMCs must take notice about these truckers economies and change the way they operate intermodal service. It would be unfortunate and even ironic that IMCs, who have done excellent job in sustaining intermodal business during the lean years of 1970, did not recognize the danger of doing business as usual and get pushed out of the intermodal marketplace. Indeed, this truckers' competitive advantage resulting from efficient equipment management, has been recognized by some principal intermodal players: several higher quality IMCs and drayers. IMCs have begun offering truck competitive intermodal services that entail a tight and complete control over all aspects of intermodal links. An example of such service is the Hub Group's BANTAM service introduced, not by accident, soon after J. B. Hunt introduced its QUANTUM service with Santa Fe (5).

Ownership and control the truckers have over their equipment puts them in a better position to satisfy customers during the periods of higher demand often resulting in railroad and third party leasing equipment shortage. However, its is not the capital ownership that matters. It is the trucker's practice of better equipment management so that he gets satisfactory return on the investment. Traditionally, IMCs not having invested in the equipment, did not pay attention to its utilization and they often behaved as a one-way travel agents. They either sent the equipment off-line without worrying how to get it back, or returned it back to the nearest rail terminal equipment pool without managing to re-load it. This resulted in inefficient utilization with long trailer cycles. Such practice is
unacceptable in the today's competitive intermodal market. The Hub Group has realized this and has begin improving the equipment utilization by finding return loads for their drayage (9). The payoff of this is two-fold. First, the productivity of drayage is increased leading to competitive drayage rates, and second, the customer service is improved because of the implicit control of the equipment the Hub has through the efficient management. In addition, the Hub, according to its chairman P. Yeager, believes that sharing the information among the parties in intermodal chain is the key for improving equipment utilization and service quality (20).

There are some indications that IMCs are sharing the information and cooperating with each other in improving equipment utilization. A good example of this is a coordination of operations between CTSI, an IMC which serves primarily the Southeast US, and its partner IMC on the West Cost (9). The CTSI notifies its sister IMC in advance of any loaded trailers/containers coming her way that will be available for re-loading. The sister IMC solicit the re-loads, and upon loading sends the trailer/container back to the CTSI. The same would take place in the reverse direction. By balancing the loads, these IMCs ensure that the equipment stays under their control, an important issue in the current environment of equipment shortage. However, it is not clear, how much of this cooperation is driven by the need to hold onto the scarce equipment as opposed to the need to make a voluntary improvement in the drayage productivity and thus in cost and service quality of the whole intermodal.

In addition there is a change in the way drayage is doing business. The competitive drayage companies are moving toward the centralized dispatching. Those with a regional service are looking at the bottom line of their whole operation rather than on the per terminal basis. They are trying to balance their loads and eliminate inefficient inter-terminal competition, which often results in nice revenues on the individual terminal profit and loss statements but poor net revenue figures for the company. In addition, the high-tech drayage carriers are entering into partnerships with intermodal long haul
truckers to do drayage for them in certain urban areas in which the trucker has no local fleet presence. Also, they are entering into partnerships with leading railroads and IMC for whom they are becoming the primary drayer and to whom they are offering competitive rates in return for the predictable volume of traffic.

The changes above indicate that some of the predictions made by Morlok and Spasovic (18) have begun to be adopted by the intermodal industry. The examples of changes in relationships indicated above seem to reflect a realization on the part of intermodal players of the need to introduce a tighter control over the intermodal chain.

8 LOOKING AHEAD TOWARD THE BIG PAYOFF

If the above proposed organizational and operational changes associated with the introduction of unified drayage were implemented, the future intermodal service will be characterized with improved service quality and reduced cost. A comparison of current and improved intermodal service is given in Table 6. It is conservatively estimated that the unified drayage operations planning would yield reduction in drayage cost of approximately 30%. The tighter control of intermodal process will result in efficient equipment management. It is expected that the trailer utilization would be substantially improved from approximately 26 days/load (13) to 6-10 days/load. This should somewhat alleviate the problem of equipment shortage.

As a result in the intermodal improvements, the industry will be dominated by a smaller number of high tech IMCs and drayers who will use information technology and sophisticated operations management procedure to offer high quality service. The competition in the marketplace will eliminate those IMCs who have failed to accept the above outlined organizational and operational improvements in the intermodal process and continued to operate inefficiently and take each other's traffic for a small reduction in drayage rate. The development and use of the decision support systems for operations planning will result in competitive and rational pricing of drayage services in particular
and intermodal service in general. The use of management information systems will result in shippers profiles and knowledge base being easily accessible thus resulting in better and more accurate servicing of customer needs. The organizational and operational improvements will result in uniform service quality and better perception of service on part of shippers. The resulting higher profit margins would stimulate the introduction of Intelligent Vehicle-Highway Systems (IVHS) technology such as Automated Vehicle Location (AVL) systems that would enable drayage to track location and status of their equipment almost continuously. This information would enable instant routing of available truck-trailers to respond to shippers requests.

The benefits of improved drayage operation are substantial. Not only will the improvement in drayage improve the service and increase the profitability of intermodal in the markets currently served by intermodal, but by reducing the threshold cost of the service and improving its quality, the break-even distance will be reduced substantially so that intermodal can compete in the largest truckload markets. This is shown in Figure 5. To illustrate the leverage that reducing drayage costs and increasing service quality can have, consider their impact on the break-even distance of 809 miles calculated earlier. If the drayage cost of $300 ($400 less typical values of $50 for sales and $50 for terminal activity) is reduced by 30%, the threshold cost would become $310. If the improved quality reduced the service inferiority adjustment premium of 15% by half to 7.5%, then the break-even distance is reduced to:

$$1.075(310) - 100)/(1.25 - (1.075)(0.70)) = 468 \text{ miles}.$$  

The break-even distance is reduced to less than half its previous value, more precisely, a reduction of 58%. While all the caveats about the applicability of this calculations to specific commodities and conditions still apply, it nevertheless indicates very persuasively the leverage of improvements in drayage have on the ability of intermodal to compete across major intercity trucking markets. A comparable reduction (30%) in any other costs element produces a much smaller reduction in the break-even
distance. Moreover, considering the improvements in cost or performance that have been made in the other major cost center (sales, terminals, and line haul), no means of creating a 30% cost reduction is foreseeable. Indeed, the only real prospect is the use of double-stack containers, and line haul savings of about 20% per container (load) have been reported, but against this must be weighed the cost of separate road chassis assemblies and the need for a unique fleet. In addition, ordinary double-stack rates are typically less than trailer-on-flat-car rates, by 5 to 10% (1), reflecting differences such as lower capacities and more difficult loading. Incorporating both these adjustments leads to a break-even distance of

\[
\frac{(1.20(400) - 100)}{1.25 - (1.20)(0.70)(0.80)} = 657 \text{ miles}
\]

only 19% less than the current estimate of 809 miles. Thus drayage improvements are clearly the key for substantially reducing the break-even distance and thereby enlarging the intermodal market.

9 CONCLUSIONS

Intermodal service suffers from both productivity and quality problems, particularly in drayage. Previous research (15,16, 17) has shown that potential exists for major and simultaneous improvements in both productivity and service quality in drayage, and hence in the overall intermodal transportation service. An especially promising approach to improvement is to reorganize the way the different players that combine to provide intermodal service relate to one another and perform various tasks. This reorganization centered on drayage service must entail the use of information on the status of loads and customers service expectations to achieve efficient scheduling and pricing of drayage movements. This is critical to intermodal becoming an effective alternative to over-the-road trucking over the spectrum of intercity markets. In addition, the change in a ways IMCs administer domestic intermodal is necessary in order to counteract the effects of increased competition from high-tech long haul truckers that are
entering partnerships with railroads. In order to stay competitive, the IMCs must lead the change in a way the intermodal is operated. The changes proposed in this paper, have enormous potential for improving cost and service quality. If implemented, they will result in intermodal becoming competitive in the shorter haul (less than 500 - 700 mile) merchandise freight traffic markets for which it was originally intended and where the bulk of truck traffic lies.
ACKNOWLEDGMENT

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TABLE 1. SHIPPERS’ REASONS FOR NOT USING INTERMODAL

<table>
<thead>
<tr>
<th>Item</th>
<th>Reasons</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transit Time Not Competitive with Truck</td>
<td>62%</td>
</tr>
<tr>
<td>2</td>
<td>Service Not Available</td>
<td>45%</td>
</tr>
<tr>
<td>3</td>
<td>Fragmented Responsibility</td>
<td>43%</td>
</tr>
<tr>
<td>4</td>
<td>Undesirable Equipment</td>
<td>28%</td>
</tr>
<tr>
<td>5</td>
<td>Unreliable Equipment</td>
<td>25%</td>
</tr>
<tr>
<td>6</td>
<td>Lack of Information</td>
<td>25%</td>
</tr>
<tr>
<td>7</td>
<td>Poor Customer Service</td>
<td>23%</td>
</tr>
<tr>
<td>8</td>
<td>Damage Problems</td>
<td>22%</td>
</tr>
<tr>
<td>9</td>
<td>Claims Problems</td>
<td>21%</td>
</tr>
<tr>
<td>10</td>
<td>Price To High</td>
<td>19%</td>
</tr>
<tr>
<td>11</td>
<td>Billing Problems</td>
<td>11%</td>
</tr>
</tbody>
</table>

Source: Temple, Barker and Sloane (11).

TABLE 2. SHIPPERS REACTIONS TO SELECTED IMPROVEMENTS IN INTERMODAL

<table>
<thead>
<tr>
<th>Type of Improvement</th>
<th>Likelihood of increasing use of intermodal</th>
<th>Willingness to pay premiums for service improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 98% of all shipment delivered as scheduled</td>
<td>69%</td>
<td>42%</td>
</tr>
<tr>
<td>2. One day faster door-to-door travel time</td>
<td>65%</td>
<td>43%</td>
</tr>
<tr>
<td>3. Unconditional service quarantines with penalty for non-performance</td>
<td>57%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Source: Richardson (12), pp. 31.
TABLE 3. DRAYAGE AS A PORTION OF THE TOTAL DOOR-TO-DOOR COST.

<table>
<thead>
<tr>
<th>Rail Line Haul (miles)</th>
<th>Cost per Mile ($/mile)</th>
<th>Rail Line Haul Cost ($)</th>
<th>Dray Time (hrs)</th>
<th>Hourly Cost ($/hr)</th>
<th>Dray Cost ($)</th>
<th>IMC Fee ($)</th>
<th>Terminal Cost ($)</th>
<th>Total Door-to-Door Cost ($)</th>
<th>Drayage as % of the Door-to-Door Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>0.7</td>
<td>350</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>770</td>
<td>42%</td>
</tr>
<tr>
<td>600</td>
<td>0.7</td>
<td>420</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>840</td>
<td>38%</td>
</tr>
<tr>
<td>700</td>
<td>0.7</td>
<td>490</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>910</td>
<td>35%</td>
</tr>
<tr>
<td>800</td>
<td>0.7</td>
<td>560</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>980</td>
<td>33%</td>
</tr>
<tr>
<td>900</td>
<td>0.7</td>
<td>630</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1050</td>
<td>30%</td>
</tr>
<tr>
<td>1000</td>
<td>0.7</td>
<td>700</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1120</td>
<td>29%</td>
</tr>
<tr>
<td>1100</td>
<td>0.7</td>
<td>770</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1190</td>
<td>27%</td>
</tr>
<tr>
<td>1200</td>
<td>0.7</td>
<td>840</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1260</td>
<td>25%</td>
</tr>
<tr>
<td>1300</td>
<td>0.7</td>
<td>910</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1330</td>
<td>24%</td>
</tr>
<tr>
<td>1400</td>
<td>0.7</td>
<td>980</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1400</td>
<td>23%</td>
</tr>
<tr>
<td>1500</td>
<td>0.7</td>
<td>1050</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>50</td>
<td>50</td>
<td>1470</td>
<td>22%</td>
</tr>
</tbody>
</table>
TABLE 4. MODEL STATEMENT

Minimize Total Drayage Tractor Ownership and Operating Costs by selecting trailer movements and locations and assigning tractors to those movements

Subject to:

- Delivering all inbound loads to receivers within specified time windows
- Delivering empty trailers to shippers for loading within specified time windows
- Picking Up loaded trailers within specified time windows and delivering them to terminal
- Repositioning trailers as they are emptied so as to avoid accumulation.
TABLE 5. ECONOMIES OF TRAFFIC DENSITY -- THE TRUCKER'S ULTIMATE ADVANTAGE

<table>
<thead>
<tr>
<th></th>
<th>Load Matching Frequency</th>
<th>Cost of Drayage Operation in the Terminal Area [$]</th>
<th>Average Cost (Rate) [$/load]</th>
<th>Reduction in Average Cost (Rate) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMC Intermodal -- Scenario 1</td>
<td>0.0</td>
<td>10,000(^4)</td>
<td>250</td>
<td>--</td>
</tr>
<tr>
<td>IMC Intermodal -- Scenario 2</td>
<td>0.5</td>
<td>7,750(^5)</td>
<td>193.75</td>
<td>--</td>
</tr>
<tr>
<td>Intermodal Trucker</td>
<td>0.8</td>
<td>57,600(^6)</td>
<td>160</td>
<td>36(^7) -- 17.4(^8)</td>
</tr>
</tbody>
</table>

\(^4\) 40 loads*$100miles /direction*2 directions*$1.25/mile = $10,000  
\(^5\) $2,750 [20 loads*$100miles /direction*1 direction*0.5*20 miles repositioning)*$1.25/mile] + $5,000 (20 loads*$100miles /direction*2 directions*$1.25/mile) = $7,750  
\(^6\) $39,600 [288 loads*$100miles /direction*1 direction*0.5*20 miles repositioning)*$1.25/mile] + $18,000 (72 loads*$100miles /direction*2 directions*$1.25/mile) = $57,600  
\(^7\) [(Average Rate for IMC Intermodal -- Scenario 1 - Average Rate Intermodal Trucker)/Average Rate for IMC Intermodal -- Scenario 1]*100%  
\(^8\) [(Average Rate for IMC Intermodal -- Scenario 2 - Average Rate Intermodal Trucker )/Average Rate for IMC Intermodal -- Scenario 2]*100%
TABLE 6. COMPARISON OF CURRENT AND IMPROVED INTERMODAL

<table>
<thead>
<tr>
<th>Features</th>
<th>Current</th>
<th>Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Base (High)</td>
<td>30% Reduction</td>
</tr>
<tr>
<td>Control Over Drayage Service</td>
<td>None</td>
<td>Complete</td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trailer Utilization</td>
<td>Poor (~26 days/load)</td>
<td>Vastly Improved (~6-10 days/load)</td>
</tr>
<tr>
<td>Image of Service</td>
<td>Poor - Fragmented</td>
<td>High Uniform</td>
</tr>
<tr>
<td>Knowledge of Shippers' Needs</td>
<td>None</td>
<td>Recorded, Accessible</td>
</tr>
<tr>
<td>Rationalization of Drayage</td>
<td>None (Average Cost Pricing)</td>
<td>Marginal Costs Known (Need Pricing Policy)</td>
</tr>
<tr>
<td>Charges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Retailers and Draymen</td>
<td>Very Large</td>
<td>Few and Selective</td>
</tr>
<tr>
<td>Adaptability to Value-Added</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Services (e.g., AVL)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 1. COSTS (INCLUDING SHIPPERS' COSTS) OF CURRENT RAIL-TRUCK INTERMODAL AND HIGH-TECH TRUCK SERVICES

Data:

<table>
<thead>
<tr>
<th></th>
<th>Intermodal</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold Cost:</td>
<td>$400/load</td>
<td>$100/load</td>
</tr>
<tr>
<td>Variable Cost:</td>
<td>$0.70/mile</td>
<td>$1.25/load</td>
</tr>
<tr>
<td>Break-even Distance :</td>
<td>545 miles</td>
<td></td>
</tr>
<tr>
<td>Shipper Cost</td>
<td>Add 15% penalty</td>
<td></td>
</tr>
<tr>
<td>Break-even Distance :</td>
<td>809 miles</td>
<td></td>
</tr>
</tbody>
</table>

Source: Morlok and Sammon (17), and Morlok et al. (22).
FIGURE 2. CURRENT ORGANIZATIONAL STRUCTURE OF DOMESTIC INTERMODAL

Shipper and Consignee ——— Intermodal Marketing Company

Drayman ——— Railroad

Direct Contact

Contact at time of pick up and delivery
FIGURE 3. PRESENT AND PROPOSED DRAYAGE OPERATION

Present: Uncoordinated Drayage

Proposed: Centralized Drayage Operations Planning
FIGURE 4. PROPOSED REDESIGN OF RELATIONSHIP AMONG PARTIES WITH CENTRALIZED DRAYAGE OPERATIONS PLANNING

Source: Morlok et al. (16), and Morlok and Sammon (17).
FIGURE 5. GENERALIZED COSTS OF CURRENT AND IMPROVED RAIL-TRUCK INTERMODAL AND HIGH-TECH TRUCK SERVICES

Data:

<table>
<thead>
<tr>
<th></th>
<th>Intermodal</th>
<th>Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold Cost:</td>
<td>$310/load</td>
<td>$100/load</td>
</tr>
<tr>
<td>Variable Cost:</td>
<td>$0.70/mile</td>
<td>$1.25/load</td>
</tr>
<tr>
<td>Shipper Cost</td>
<td>7.5% penalty</td>
<td></td>
</tr>
<tr>
<td>30 % reduction in drayage cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Break-even Distance : 468 miles

Source: Morlok et al. (22)