SIMULATION OF DEDICATED FLEET OPERATIONS IN THE RAILROAD INDUSTRY

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I. INTRODUCTION

A practice of increasing importance in the railroad industry is that of dedicating freight cars for the use of a particular shipper. Such cars are said to be in assigned service. Typically, these cars are loaded at a particular point in the network, are transported to an unloading point, are made empty and are returned empty to the originating point. The car is then reloaded for a new destination (perhaps the same one as previously) and the process repeats. Usually, there is no backhaul load. Through the assigned fleet mechanism, shippers may be guaranteed a supply of cars for loading, even in times of car shortage and in fact, complaints by shippers of a persistent car shortage are the most frequent causes for dedicating a pool of freight cars for the use of one shipper. Such cars may be owned or leased by the shipper or railroads may assign certain cars of their own for that purpose.

Theoretically, assigned fleets should lead to less efficient car utilization because of one-way loaded moves and empty return over the same route. That is, the ratio of empty car-miles to total car-miles is 0.5 for assigned fleets and is greater for free-running cars which can be loaded more efficiently. However, if utilization is measured by the total cycle time, (the time between successive loadings of a car), the utilization of assigned fleets has paradoxially been at least as good as that of free running cars. Among the reasons for this are that empty free-running cars (i.e. non-assigned cars), often spend excessive amounts of time between loads due to empty car distribution practices and excessive time waiting to be loaded and unloaded. On the other hand, assigned fleet service allows better utilization of shipper-owned or leased cars by providing the incentive to load to capacity, to use the best service routes and to minimize loading and unloading time. The shipper has the flexibility of using any car for any load and he can send it in any direction, without being constrained by any car service orders. The consequences of these actions in assigned fleets tend to reduce the car cycle time and result in better car availability, when compared to free-runners. If using assigned fleet service significantly reduces cycle time, then the car supply of the non-assigned user can also be improved, when both compete for the same car supply.(1) Assigned fleets also assure reliability of car supply, which can be matched to the traffic levels such that shipping schedules can be made to correspond with production schedules, minimizing delays for both railroad and customer. By forecasting the production of goods to be loaded on cars and knowing the trip times and reliability of car movements, fleet sizes can be anticipated and carefully controlled to allow the highest possible utilization of cars for any desired level of service.

Often assigned fleets are made up of specialized, expensive equipment. For example, enclosed tri-level autorack cars, for transporting assembled automobiles, are among the most expensive of railroad freight cars. These are almost invariably in assigned fleets. Thus, sizing the assigned fleet is a key issue. The trade-off is that between level of service being provided to the shipper and the utilization of the assigned fleet.

In simplest terms, if the fleet is oversized, cars will always be available for loading and unloading which amounts to "optimal" service. However, utilization of the fleet will be poor since cars will spend a great deal of time waiting to be loaded or unloaded. Thus, costs will escalate. Also, as will be seen, there are strategies available to the railroad(s) providing the service and to the shipper for improving utilization and service for a fleet of a given size. Of course, these strategies can also be used to reduce the fleet size required to provide a given level of service. These strategies are discussed in Section II.

In practice shippers and railroads operate as separate entities, each seeking to maximize their own revenues from using an assigned fleet. Any strategy which affects performance should result in savings to the actor responsible for them in order to make the changes economically feasible for him. Otherwise, there will be little motivation for making improvements which will benefit the other party, unless the action is reciprocated. For each strategy analyzed, trade-offs between level of service and car utilization must be predicted. The relative impacts of these strategies on the actors involved can then be used to determine the appropriate actions of both parties.

A simulation model was developed to consider the trade-offs noted above. The model is really rather simple in design and implementation and hopefully is illustrative of how, in certain cases, a non-complex modeling approach can lead to useful and usable results.

II. STRATEGIES FOR IMPROVEMENT

There are a number of strategies available to the railroads in operating an assigned fleet and to the shipper/receiver in operating his logistics system. These strategies should lead to improved service, improved utilization or both. In Section III, a model designed to explicitly consider the impact of these actions is described.

Increase Fleet Size - Railroads are typically responsible for supplementing the assigned fleet with additional cars to improve level of service being provided to a shipper. However, an excess fleet size will often result in higher demurrage costs to a shipper due to longer wait times of cars at the siding. A shippper, depending on the arrangement, may also be responsible for storage costs if a railroad car is sitting idle at a terminal yard in non-revenue service. Such costs will occur more frequently if fleets are oversized. Excess cars may also necessitate higher switching costs due to congestion at the sidings.

The costs to a railroad of providing additional cars are rather complex. First of all, there are increased operating costs from running longer trains or more frequent service. More important, there is an opportunity cost to a railroad for adding too many cars to an assigned fleet, but this depends on the demand for those cars in other parts of the system. If there is a deficit of those cars and demand for them exists, then there is a loss of revenue which could have been obtained elsewhere. The loss is somewhat offset by shipper payments of demurrage and/or storage fees. A shipper pays demurrage if he holds a car an excessive amount of time, while storage fees accrue if a car must be held at a yard an excessive amount of time prior to placement. In a car surplus situation, these fees will at least cover some of the losses but will not usually cover the costs of owning the car, however. The exact nature of these fees and costs is complex and is frequently subject to agreements between shipper and railroad. If a shipper has privately owned or leased cars in his pool, then he will also be strongly motivated to improve car utilization with the potential of eliminating cars of his own from the fleet or at least delaying the purchase of additional equipment.

Improve Mean Trip Time and Reliability - Another strategy for improving the availability of empties is to improve railroad operating performance between origin and destination. It is clear that the average transit time between origin and destination is a factor in computing the number of cars needed. Also the variability in this transit time is important in this determination as well. This variability, often called service reliability(2), is a problem of some concern in the rail industry and the relation between service reliability and car utilization is a topic of a major rail industry research effort. (3)

Thus, improvements in transit time and transit time reliability, can be used to reduce fleet size while holding level of service to the shipper constant. The idea is to combine railroad operating performance improvements with appropriate fleet size adjustments to insure optimum car utilization, consistent with providing an adequate level of service. Railroad operating improvements in themselves usually do not result in cost savings, but the resulting decreases in fleet size will reduce railroad costs and release cars for use elsewhere, and they might result in delaying investment in new cars. As long as shipper level of service does not deteriorate, the shipper will not be affected by fleet size decreases. In fact, under certain arrangements, he will be paying less demurrage and/or storage fees and he may be able to reduce the number of his own cars in the fleet or at least postpone purchasing or leasing of additional cars.

Increase Loading and Unloading Rates - A customer can reduce his detention time by expediting the loading and unloading process, up to a certain level. Such customer practices take the form of improved physical facilities, more efficient terminal switching and better operations control. Examples of shipper-related strategies can be found in a recent report summarizing practices relating to car utilization.(4) These strategies result in higher car utilization which benefits both shipper and railroad. For example, the shipper is motivated to increase the loading/unloading rates if he can reduce the number of his own cars in the fleet. Faster loading and unloading will also decrease demurrage costs to the shipper because fewer cars will be waiting at the sidings. If level of service is inadequate, these actions can result in service improvements to the shipper. As will be shown later, higher loading/unloading rates allow even smaller fleet sizes if less than maximimum level of service (defined as when empty cars are always available to the shipper and no stockouts occur of loaded goods at the receiver) can be tolerated.

Increase Warehouse Capacity - The explicit interaction between railroad performance and the production system of the shipper involves the use of an inventory of goods in a warehouse. This inventory serves as a buffer to protect against fluctuating production and customer demand, and uncertain car arrivals. Providing additional warehouse capacity increases the buffer size, offering a higher level of service. The resulting decrease in detention time can improve car utilization and reduce railroad operating costs. A receiver can be motivated to provide additional warehouse capacity since it can improve his own level of service. It will also reduce his demurrage and/or storage fees and can reduce the number of cars in the fleet.

III. SIMULATION MODEL STRUCTURE

The complexity of the assigned fleet problem and the desire to gain insight into the basic relationships among the variables of interest led to a simulation model approach. The model was structured to be generally applicable for a "first-cut" analysis but detailed enough to be useful for specific situations involving actual shipper or railroad operations changes. In the context of this study, the model was used to examine railroad and shipper operating level decisions in order to determine their relative effectiveness and typical magnitudes of changes and results which might be expected. It is very flexible in its structure, following a gradual development from a simple two-node network with few policy-sensitive options to a model which can be easily modified for multiple destinations, involving decision rules for routing and many combinations of possible strategies for improving service to selected destinations.

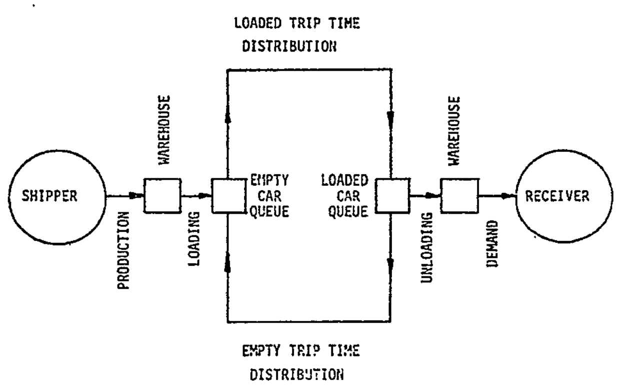
The basic model structure is a two-node network in which all loads are generated by a shipper for use by a receiver who unloads the cars and returns the empties to the same shipper. A "load" is defined as a quantity of goods produced by the shipper which will fill a car, i.e. it is a carload of finished goods. As shown in Figure 1, the shipper and receiver maintain inventories of empty and loaded cars, respectively. The simulation is initialized with a given fleet size at the shipper's siding. As loads are generated on a daily basis, they pass to a warehouse and are loaded on cars, if there is an empty car available. If an empty car is not available, the load remains in the warehouse and waits until one arrives. Empty cars are loaded in a first in-first out sequence until one of the following occurs:

1. There are no more loads in the warehouse.
2. There are no more empty cars available to be loaded.
3. The daily maximum loading rate has been reached.

The maximum load rate is an input which describes the physical ability of the shipper to load empty cars given that there are sufficient loads in the warehouse and empty cars are available. For example, if the maximum load rate is 15 cars per day, then only that number will be loaded even if there are 20 loads in the warehouse and 20 empty cars await loading.

FIGURE 1

SIMULATION MODEL STRUCTURE



Once the cars are loaded, they are released to the railroad. The trip time to the receiver is a discrete random variable having a distribution which is an input to the model. The unreliability of railroad service for a particular origin-to-destination pair results in a range of trip times over a period of time. The mean of this probability distribution is the average transit time while the "spread" indicates the reliability of the service. Operating changes on a micro-level result in changes in trip times for individual cars which are affected. When aggregated into a trip time distribution, the effects of the operating changes can be seen on a macro-level by observing the change in the shape and position of the trip time distribution. Independent samples of this probability distribution determine the transit time for a particular day's block of cars released by the shipper.

Upon arriving at the receiver, the cars join the loaded car queue. An unloading process begins, analogous to the loading process at the shipper. The receiver has a daily demand for loaded cars which is necessary to satisfy his own production schedule or to meet customer demands. Whenever this daily demand is not met, the unfilled requirement is placed in an "order backlog". Loaded cars are unloaded until one of the following occurs:

1. The cumulative demand has been met and the order backlog has disappeared.
2. There are no more loaded cars to be unloaded.
3. The daily maximum unloading rate has been reached.

For example, suppose the daily demand is 100 loads per day and two days have gone by. Then the cumulative demand is 200 loads, but if only 190 cars have been unloaded up to that day, then the order backlog consists of 10 cars. If the maximum unloading rate is 15 cars per day, then only 10 cars will be unloaded, that is, up to the amount of the order backlog. If there are only 8 loaded cars available, there will be a remaining order backlog of 2 loads.

Once the cars are unloaded they are released to the railroad and proceed back to the shipper as determined by the empty trip time distribution. The model operates by sending cars through the cycle for any desired number of days.

IV. RESULTS

The results of the application of the model are twofold. First, there are so-called "experimental" results. These results are derived from several hypothetical situations that can be useful in demonstrating the kind of results that can be produced from the model and in illustrating the design tradeoffs that exist in structuring of assigned fleets. The second set of results is the application of the model to a real situation involving a major railroad and a shipper they serve with an assigned fleet. This case study led to the evaluation of several implementable strategies and the demonstration of the usefulness of the model in a real world context.

IV-A. Experimental Results

In the experimental runs to follow, several simplifying assumptions concerning the shipper's logistics functions have been made. Production is assumed to be the same each day and is equal to the demand at the receiver which is also a daily constant. This assumption is often not valid, but is reasonable in the assigned fleet case. Shippers using assigned fleets are typically interested in a "pipeline" distribution system such that there is minimal disruption to the production process. Costs of production start-up or shutdown are assumed to be so high that every effort is made to minimize their occurence.

Variations in empty car availability result in a backlog of produced goods which are stored in the shipper's warehouse (assumed to be of adequate capacity). If the fleet is sized such that empty cars are always available, there would be no such inventory. Otherwise, the size of this backlog is one indication of the level of service being experienced in the system. This can be measured by the mean wait time to load, defined as the average time between production of a good and its loading on an available car, or the mean time goods spend in the warehouse.

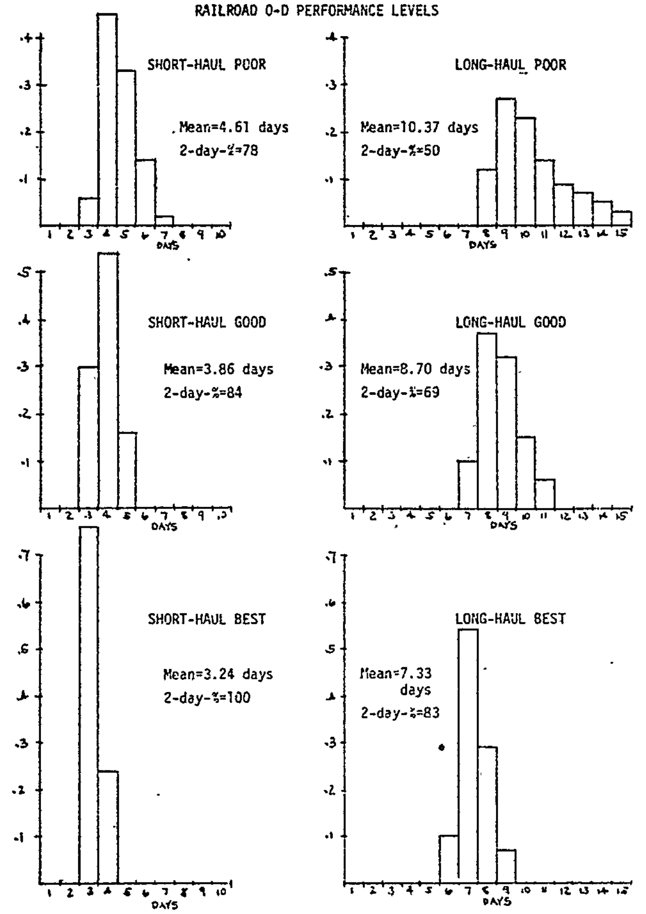
At the receiver, cars are unloaded to satisfy external demands. If a warehouse is available, goods can be unloaded and a buffer stock accumulated to protect against future uncertain car arrivals. Providing warehouse capacity is one of the four strategies to be examined. Level of service is measured by the number of stockouts and is strongly correlated with the mean wait time to load at the shipper.

Another factor in assigned fleet situations is general railroad operating performance between the origin and destination pairs served since assigned cars will typically travel on road trains along with other traffic. Indeed, railroad operating performance has been the subject of much research for several years. Various models have been developed to predict the trip time distribution between origin and destination as a function of the number and types types of classification yards, train frequencies, scheduling policies and other operating parameters, in an effort to improve service reliability. It has been found that efforts to improve reliability also often result in a decrease in mean trip time. These changes in operating policies are much less expensive than capital improvements and are implementable very quickly.

Figure 2 shows typical origin-destination trip time distributions for short and long trips as they were inputted to the simulation model. The "base case" corresponding to poor service for each set involves an assigned fleet experiencing O-D service that is somewhat unreliable relative to typical rail performance for trips of that length. These distributions are synthesized from actual railroad data. Levels of improvement are reasonable ones relative to previous research experience and actual improvements achieved by railroads. As shown in Figure 2 two faster and more reliable trip time distributions are used to represent improvements over each base case. The shape of these distributions and the nature of improvements which they represent were chosen to reflect the manner in which actual trip time distributions would change. Thus, one would expect that more potential for improvement exists for long-haul trips, in terms of the actual trip time and reliability. This is because longer trips involve more yard classifications, whose performance can be improved or which can be bypassed. Each improvement in O-D performance represents a 16% decrease in mean trip time and the associated 2-day-%(5) as compared to the previous one, for both long-haul and short-haul trips. Trip time distributions are the same for both the empty and loaded moves in the experiments.

FIGURE 2

RAILROAD O-D PERFORMANCE LEVELS



In addition to improvements in O-D performance, each set of model runs contains improvements in loading/unloading rates and receiver warehouse capacity. The common parameter varied for each run was the number of cars in the fleet, allowing each improvement to be evaluated over a range of fleet sizes, from 700 cars to 1300 cars. The base case represents the most constrained shipper behavior possible. In this case loading and unloading rates are equal to the daily production and demand rate assumed to be 100 loads per day. No warehouse capacity is available for unloading at the receiver in this scenario.

Results of the short-haul runs are seen in Figures 3 through 7. For the base case, a minimum of 1200 cars is required to provide adequate service. If fewer cars are used, goods will constantly accumulate in the shippers warehouse and will not all be loaded in the long run. In that case, a different mode would be used or the fleet would be supplemented with General Service cars, if they were available. If more than 1200 cars are used, no additional service improvements are evident, but utilization declines as seen in Figure 7. Improving O-D performance results in a 200-car reduction in each case. In Figure 4, O-D performance is improved at a higher load/unload rate which is more representative of typical shipper behavior. Larger fleet reductions are possible due to faster loading and unloading. Furthermore, if the shipper is willing to tolerate an inventory of goods and the receiver accepts occasional stockouts, additional reductions are possible with concurrent improvements in car utilization.

FIGURE 3

SHORT-HAUL LEVEL OF SERVICE VS. FLEET SIZE: IMPROVE O-D PERFORMANCE

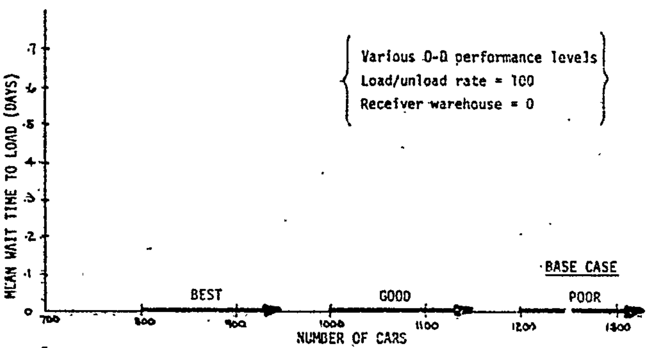


FIGURE 4

SHORT-HAUL LEVEL OF SERVICE VS. FLEET SIZE: IMPROVE O-D PERFORMANCE WITH A HIGHER LOAD/UNLOAD RATE

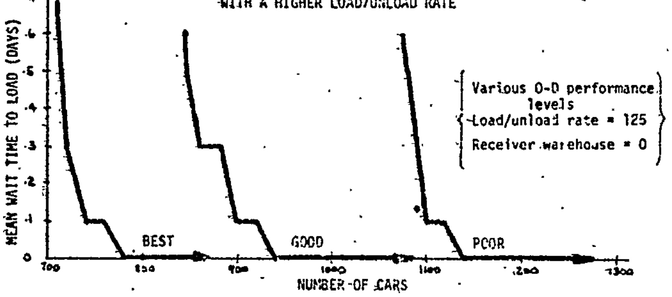


FIGURE 5

SHORT-HAUL LEVEL OF SERVICE VS. FLEET SIZE: INCREASE LOAD/UNLOAD RATES

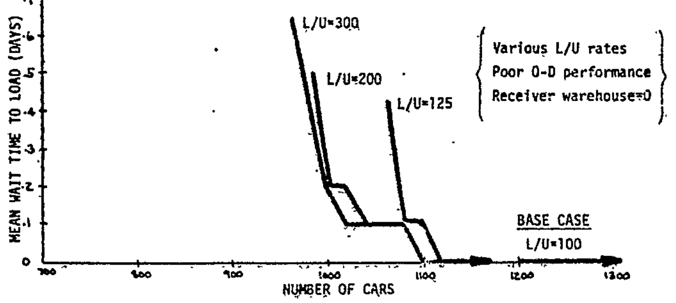


FIGURE 6

SHORT-HAUL LEVEL OF SERVICE VS. FLEET SIZE: INCREASE LOAD/UNLOAD RATES, ADD RECEIVER WAREHOUSE CAPACITY

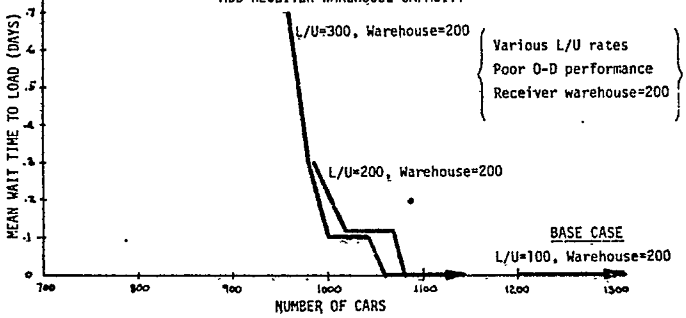
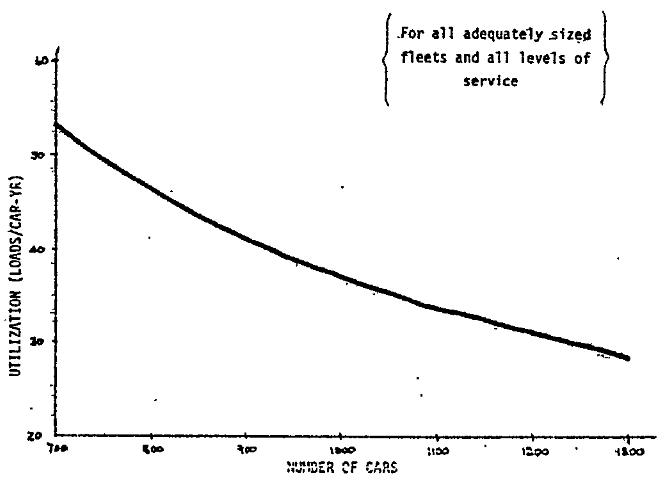


FIGURE 7

SHORT-HAUL CAR UTILIZATION VS. FLEET SIZE



The effects of additional increases in loading and unloading rates, for poor O-D performance, can be seen in Figure 5. Decreasing marginal returns from this strategy are apparent. Also, although not shown here, these improvements decrease the loaded and empty car queues, reducing demurrage costs to the shipper and receiver.

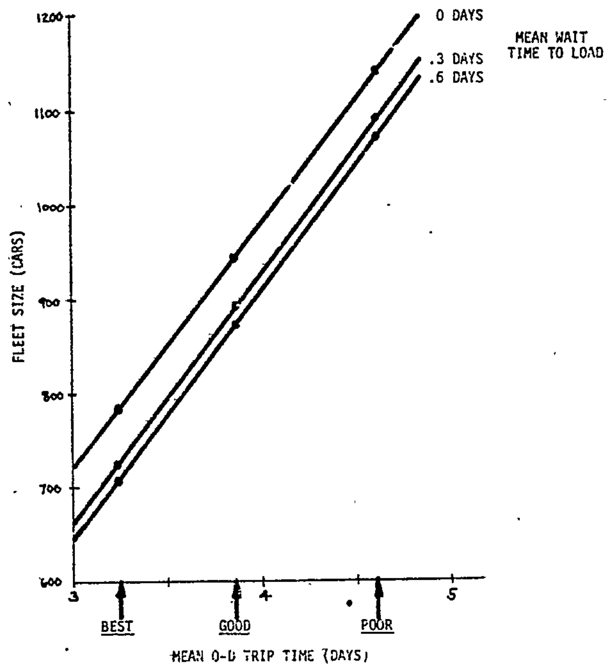
Addition of warehouse capacity, in Figure 6, is seen to have very little impact on overall level of service. However, it was seen to result in the transfer of car queues from the receiver to the shipper. This could be very useful for receiver with limited siding capacity, while the additional empty cars at the shipper would be more important for multiple destination assigned fleets. One would expect this strategy to be more effective if receiver demand were stochastic, since the additional inventory in the warehouse would act as a buffer against uncertain demand as well as uncertain car arrivals.

In repeating the above analysis for typical long-haul movements and their accompanying improvements in reliability, little relative difference was found between the strategies. Longer haul trips are generally much more unreliable than shorter-haul trips and involve more yard classifications. Therefore, the expected magnitude of improvements and subsequent fleet size reductions are larger. Due to the greater unreliability of longer-haul trips, providing warehouse space at the receiver as a buffer against uncertain car arrivals had relatively more impact than it did in the short-haul runs. For brevity's sake, these results are not shown here.

In general, it is evident that even relatively modest improvements in railroad O-D performance are at least as effective as the most ambitious shipper strategies considered here in improving car utilization and level of service. A railroad is motivated to improve O-D performance because it will achieve the needed service improvements a shipper may be asking for, without adding cars to the fleet. Improving O-D service can result in fleet size reductions and improved car utilization. This is a worthwhile goal for any railroad to pursue, given the increasing costs of purchasing and maintaining railroad cars. Of course, there are secondary benefits of improved operating performance accruing to other shippers using the railroad and possibly increased revenues from making excess cars available to them.

A shipper will increase load/unload rates and add warehouse capacity if the cost of those improvements can be offset by savings in inventory holding costs, stockout costs, and possibly demurrage. If a shipper also has cars of his own in the fleets, he will also benefit from the resulting car utilization improvements. If the fleet is being supplemented with free-runners, any contemplated improvements should consider their cost against those of using assigned cars. Other benefits of shipper actions may result from mutual agreements between the shipper and the railroad. The results of the model should aid in prediction of anticipated changes. Figure 8 shows isoservice curves which can be useful in such an analysis. They show the benefits of trip time reductions for various levels of service which a shipper is willing to accept. Similar curves could be constructed for load/unload rate improvements and addition of warehouse capacity by the receiver.

FIGURE 8
ISOSERVICE CURVES FOR TYPICAL SHIPPER BEHAVIOR
(SHORT-HAUL, LOAD/UNLOAD RATE = 125, RECEIVER WAREHOUSE = 0)



IV-B. A Case Study Of An Assigned Fleet

The assigned fleet simulation model was modified to analyze improvement of service to a shipper using an assigned fleet. The problem is a typical one facing shippers and railroads involved in assigned fleet use -- the shipper is not always completely satisfied with the service he is experiencing, while the railroad feels the fleet is adequate but the utilization of the fleet is less than expected. Neither shipper nor railroad is able to ascertain the cause of the problem, or to predict the impacts of possible solutions. The analysis in this section uses data from both parties to help in selecting the appropriate strategies to improve service to the shipper and to improve car utilization. The model will be used to test the relative impacts of various strategies, rather than to make accurate predictions of the absolute magnitudes of the results.

A large shipper wishes to improve performance of its assigned fleet, since the shipper is experiencing an uneven flow of empty cars to be reloaded at the plant. The use of the assigned fleet of 1300-1400 cars for the shipper does not require matching orders with rail cars of specific ownership, but allows the flexibility of loading any available cars to approximately 30 destinations. An adequate empty car supply at the plant is necessary to fill orders and prevent plant shutdown, but at times it is impossible to assure such a supply. Nevertheless, it is felt that there are enough cars in the fleet but they move so unreliably that service is sometimes poor. The car turnaround of about 1.4 loads/car-month is thought to be excessive and it is known that empty cars are not moved as rapidly as loaded cars.

The simulation model was modified to conform with available data but to give results meaningful to the shipper and railroad. Since it was not known when the various receivers obtained loaded cars, the analysis was limited to shipper and railroad strategies. An aggregate trip time distribution representing trips to all receivers was synthesized from car movement records, with a mean of 19.7 days. Since shipments to various destinations were approximately uniform over time, this was felt to be a reasonable approximation. Historical loading data revealed a definite daily variation due to truck loading schedules which was incorporated into the model. A waybill processing delay (no-bill) was explicitly modeled, as well as Sunday shutdown of the local outbound yard. Goods which waited more than one day in the shippers warehouse (its effective capacity) were not loaded on assigned cars, i.e. they were put on free-runners which are used to supplement the fleet.

Table 2 shows the actual and predicted results, while Tables 3 and 4 show the effects of various strategies. A two-day reduction in the loaded and empty trip time (about 10%) is a more effective way to improve service and car utilization than any of the shipper strategies.

This reduction in trip time can be a result of:

1. Better service by the railroad
2. An improvement in performance of other connecting railroads
3. Changes in routing or the pattern of loading to the receivers
4. A reduction in receiver detention time.

Table 2

ACTUAL VS. PREDICTED SIMULATION RESULTS FOR THE SHIPPER'S ASSIGNED FLEET

	Actual	Predicted
Fleet Size	1377 Cars	1400 Cars[1]
Shipper Empty Queue Detention	29 Hours	1.0 Days
No. of Loads in the Shipper's Warehouse	About one day's production, or 70 loads	65 Loads
Percent of Free-runners Used	2%	4%

[1] Input to the model.

Table 3

RAILROAD STRATEGIES TO IMPROVE PERFORMANCE OF THE SHIPPER'S ASSIGNED FLEET

	STRATEGY	FLEET SIZE	UTILIZATION (Loads/Car-Yr)	PERCENT FREE-RUNNERS	SHIPPER'S EMPTY QUEUE	LOADS IN WAREHOUSE
	BASE CASE	1400	17.2	4%	64 Cars	65 Loads
RR-1	ADD 100 CARS	1500	16.8	1%	106 Cars	63 Loads
	ADD 150 CARS	1550	16.4	None	142 Cars	24 Loads
RR-2	REMOVE 100 CARS	1300	17.5	10%	36 Cars	68 Loads
	REMOVE 200 CARS	1200	17.5	16%	24 Cars	71 Loads
RR-3	OPERATE YARD A ON SUNDAYS	1400	17.8	2%	90 Cars	63 Loads
	ADD 100 CARS	1500	16.9	None	161 Cars	11 Loads
RR-4	REDUCE TOTAL TRIP TIME BY 2 DAYS	1400	18.1	None	135 Cars	50 Loads
	ADD 50 CARS	1450	17.5	None	181 Cars	11 Loads
RR-5	REDUCE TOTAL TRIP TIME BY 4 DAYS	1400	18.0	None	271 Cars	11 Loads
	REMOVE 100 CARS	1300	19.5	None	171 Cars	11 Loads
	REMOVE 150 CARS	1250	20.2	None	125 Cars	57 Loads

Table 4

SHIPPER STRATEGIES TO IMPROVE PERFORMANCE OF THE SHIPPER'S ASSIGNED FLEET

	STRATEGY	FLEET SIZE	UTILIZATION (Loads/Car-Yr)	PERCENT FREE-RUNNERS	SHIPPER'S EMPTY QUEUE	LOADS IN WAREHOUSE
	BASE CASE	1400	17.2	4%	64 Cars	65 Loads
SH-1	ELIMINATE NO-BILL DELAY	1400	17.3	4%	68 Cars	64 Loads
	ADD 150 CARS	1550	16.4	None	152 Cars	14 Loads
SH-2	LOAD EVENLY THROUGHOUT WEEK AT 24 CARS/SHIFT	1400	17.5	3%	35 Cars	30 Loads
	ADD 100 CARS	1500	16.9	None	89 Cars	4 Loads
SH-3	LOAD EVENLY THROUGHOUT WEEK, INCREASING LOADING TO 30 CARS/ SHIFT	1400	17.6	3%	32 Cars	24 Loads
	ADD 100 CARS	1500	16.9	None	90 Cars	2 Loads

This two-day reduction in the trip time could result in a major service improvement to the shipper without the addition of 150 cars which would otherwise be necessary. However, the shipper will be paying demurrage and/or storage fees, based on a queue increase of about 70 empty cars over the existing case. This queue would only be 90 cars long if loading were uniform, but 100 additional cars would still be required to provide the same service. It seems unlikely that the cost to the shipper of loading cars evenly and the cost of the additional

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100 cars can be offset by smaller demurrage and/or storage fees, when compared to the railroad actions.

A one-day reduction in trip time in each direction (2 days in all) appears to be a worthwhile goal for the railroad and the distributors to pursue. On the railroad's part, this might be achieved by using more run-through trains and more efficient handling of cars, particularly in the long-haul off-line movements. The shipper and the railroad should examine the feasibility of pre-blocking cars at the shipper, by destination and/or railroad, in order to reduce the mean trip time. The cost of such a change would appear to be small relative to the potential benefits in car utilization and level of service.

Thus, it is seen that various strategies lead to improvements in car utilization and service (as measured in several ways). However, the reader should note that an ultimate decision on what to do should be based on a complete assessment of all the costs involved, using this model to predict the magnitude of improvements. At the conclusion of such an analysis, it is hoped that an actual implementation of some of these strategies will take place.

V. SUMMARY

A simple simulation model of assigned fleet operation has been described and applied to both a hypothetical set of conditions and a "real-world" situation. The model was useful in studying the trade-offs in the design of a particular assigned fleet. A comparative study of the various available options was carried out and the impact of these options on both the railroad(s) involved and the shipper are now better understood. The hoped for next step is the implementation of these strategies in actual operation practice.

In closing, it is again worth noting the simplicity of the model used in this work. This model is a "one day at a time" form with no complex event structure underlying it. A large amount of the effort involved in this study was concerned with the exercising of the model, both for the purpose of gaining basic insight into the process and for the study of the particular assigned fleet situation.

The model was designed with a particular set of goals and trade-off evaluations in mind. Close liaison with the industry was maintained during its development and particularly during its application. Through these procedures, it is hoped that, despite its simplicity, the model can be useful for a broad range of assigned fleet problems in the rail industry.

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5. 2-Day-% is defined as the maximum percentage of cars arriving in a contiguous 2-day window. This is often used as a reliability measure in the rail industry.

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