

# The Effects of Trailer Scheduling on the Layout of Freight Terminals

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## **Abstract**

Supervisors in a less-than-truckload freight terminal establish material flows inside the terminal by assigning incoming trailers to open doors. A common scheduling strategy is to “look-ahead” into the queue of incoming trailers and assign them to doors to minimize worker travel. We develop a model of the resulting material flows and use it to construct layouts that exploit this type of scheduling policy. Based on data from a test site, our results suggest that look-ahead scheduling alone can reduce labor costs due to travel by 15–20% compared to a first-come, first-served policy. Layouts constructed with the material flow model provide further savings of 3–30% in labor cost due to travel, depending on the mix of freight on incoming trailers and the length of the queue of trailers from which the supervisor makes assignments.

Freight terminals in the less-than-truckload (LTL) motor carrier industry are facilities in which shipments are unloaded, sorted and consolidated, and loaded onto outgoing trailers for delivery elsewhere in the system. The largest LTL carriers spend \$300–500 million annually handling freight (about 20% of total costs), and approximately 10–15% of that cost is due to workers traveling the dock while transferring freight from incoming to outgoing trailers. Thus our work has the potential to affect approximately 2–3% of the total costs of a carrier. This small percentage is significant because of the thin profit margins posted by most large carriers. In fact, none of the three largest carriers (Yellow Freight, Roadway Express, or Consolidated Freightways) posted more than a 2% profit in the years 1994–96, and all lost money in at least one of those years (Bowman, 1996).

In addition to being costly, freight handling is important because time that a shipment spends at the terminal is “wasted,” in the sense that the shipment is not making progress toward its final destination. In some cases, rapid turnaround in the terminal can mean the difference between providing overnight or second-day service to a destination.

Terminals in the LTL industry serve three basic functions, called the *outbound*, *inbound*, and *breakbulk* operations. Outbound operations occur in the evening, after pickup and delivery (P&D) trucks return from their routes in a local area. Freight is sorted and consolidated onto trailers heading for other points in the system; thus the freight is “outbound” with respect to the local area of the terminal. In the early morning, the inbound operation receives trailers from other terminals. Freight is sorted onto P&D trucks for local delivery during the day; this freight is “inbound” with respect to the local area. Some terminals also serve as breakbulks, meaning they act as mid-way consolidation points for freight which neither originated from, nor is destined for, the local area of the terminal. Generally speaking, all terminals have inbound and outbound operations, and some also serve as breakbulks.

Depending on the size of the terminal, a typical workforce contains an operations manager, 2–4 supervisors, and 2–3 dozen workers. Usually, one or more

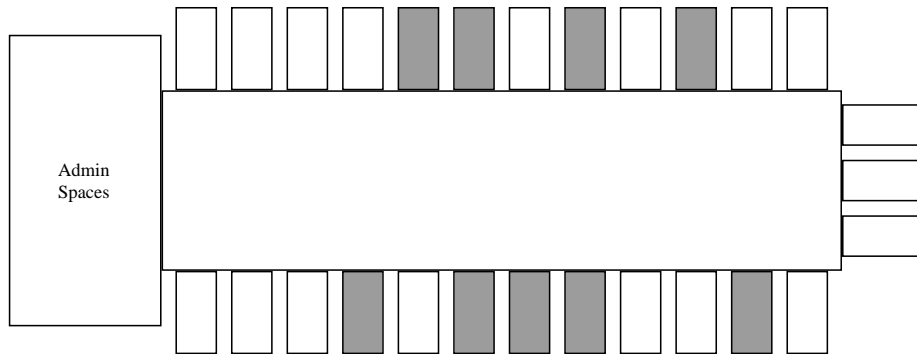


Figure 1: A typical LTL terminal. Shaded rectangles represent incoming trucks.

supervisors is responsible solely for assigning incoming trailers to doors. The remaining supervisors oversee the workers and ensure that departing trailers are closed out and available for dispatch on time.

When an incoming trailer arrives at the terminal, a supervisor may assign it to an open door; or, if none is available, he may send it to a queue of trailers in the yard, and call for it later. The queue of arriving trailers can range in size from a few to 20 or more. Once the incoming trailer is parked at an open door, workers unload its shipments and deliver them to doors designated to receive freight for specific destinations. The unloading continues until the incoming trailer is empty; then a driver pulls the trailer away and replaces it with another incoming trailer of the supervisor's choosing. When an outgoing trailer is full, a supervisor orders it closed and replaces it with an empty trailer that accumulates freight for the same destination.

Figure 1 illustrates a typical LTL terminal, which resembles a large, open-area warehouse, with dock doors along the perimeter. LTL terminals range in size from 6–8 doors to more than 200. A terminal we visited in Dallas, TX, which we were told is the largest in the world, has more than 500 doors.

There are two types of doors in a terminal: receiving doors, called *strip doors*, and shipping doors, or *stack doors*. A strip door receives only incoming trailers with freight to be unloaded. A stack door is designated to receive freight

for a single destination. When the outgoing trailer for that destination is full, it is replaced with an empty trailer bound for the same destination. We define the terminal *layout* to be the arrangement of strip doors and stack doors, and the assignment of destinations to stack doors.

The layout establishes material flows in the terminal and the travel distances for workers transporting freight. Workers are more productive when incoming trailers are nearer the appropriate destination trailers, because this reduces travel distances. Thus, supervisors try to assign incoming trailers to doors close to the destination trailers for which they have the most freight.

This can be a difficult task, because the supervisor must consider other issues when making an assignment. For example, an incoming trailer may get priority if it contains a shipment that requires rapid turnaround; or the supervisor may choose a trailer based on the type of shipments inside (pallets or cartons), rather than their destinations, in order to balance work among different material handling modes. Despite these competing considerations, the supervisor's overriding goal is to make assignments that minimize work, and this almost always involves minimizing worker travel.

For an established layout, the supervisor is faced with a scheduling problem analogous to a parallel machines scheduling problem, in which the processing time for each job (trailer) depends on the machine (door) to which it is assigned. But in a freight terminal, managers can establish those processing times by changing the layout.

In practice, managers at some terminals construct layouts that implicitly account for the supervisor's scheduling policy. This is usually manifested by having the highest-flow destinations in different sections of the dock. Some managers believe that this allows more strip doors to be near those destinations, so that when a trailer arrives with much freight for one of those destinations, the supervisor has a greater chance of assigning it to a good door. All such layouts that we have seen have been constructed based on intuition, or perhaps with the help of some simple spreadsheet calculations.

Other authors have proposed solutions to layout problems for freight termi-

nals (Bartholdi and Gue, 1997; Peck, 1983; Tsui and Chang, 1990, 1992), but in every case, freight flows from strip doors to destinations were assumed to be known and independent of the layout. If the supervisor assigns incoming trailers to doors based on the contents of the trailers waiting in the queue and the location of the doors (we call this *look-ahead* scheduling), material flows *depend on* the layout. We know of no existing literature on layout problems in which material flows depend on the layout of a facility.

We solve two problems to produce a layout: First, we estimate the labor cost of material flows caused by look-ahead scheduling for a given layout; and second, we search the solution space of all layouts to determine the layout with lowest cost. Even for fixed material flows between strip doors and destinations, finding an optimal layout is a difficult combinatorial problem. Computing as a subproblem the material flows for each layout makes it more difficult. Our strategy, then, is to specify a model of material flows that we can solve quickly, and embed that model within a local search algorithm to find a near-optimal layout.

Our approach for the first problem is to construct a parametric model of material flows that accounts for the supervisor's look-ahead scheduling policy. The parameter of the model represents the level of *influence* that the supervisor has over flows in the terminal. We will show that the level of influence depends on the mix of freight in the incoming trailers and on the length of the queue of trailers from which the supervisor makes assignments.

For the second problem we use a local search algorithm to find the best layout for a given level of influence. Because it is difficult to characterize the level of influence explicitly, we use the model to generate a number of layouts, each corresponding to a different level of influence, and determine the layout having the lowest cost with simulation.

We develop three main results:

1. Carriers can save 15–20% in labor costs due to travel (3–4% of total labor costs) in a terminal by using a look-ahead scheduling policy for incoming

trailers. This is in contrast to the first-come, first-served (FCFS) policy used by many terminals.

2. For the freight mix in the trailers from our test site, there was only a slight advantage to using a layout based on the altered material flows caused by a look-ahead scheduling policy. A layout constructed with a simple model based on “average flows” performed almost as well.
3. Layouts constructed with a model of altered flows can yield significant savings in travel, if the average number of destinations per trailer is low. Under this condition, the supervisor has more influence on the material flows, and layouts constructed with the model of altered flows performed much better than those that did not.

## 1 Model

In practice, supervisors at many terminals assign incoming trailers to doors without regard to the destinations of the freight inside. This may happen for several reasons:

- The mix of freight on the dock causes him to choose a trailer based on the type of freight (meaning pallet or carton freight), rather than on the destinations of the shipments;
- There is no decision support system to help make the assignment; or
- Trailers are routinely served first-come, first-served to minimize double handling in the yard.

Under such conditions, the supervisor’s policy is equivalent to a FCFS policy (with respect to the destinations of shipments), and each strip door sees the same distribution of freight in the long run (Gue, 1995).

To compute the costs of the FCFS policy, Bartholdi and Gue (1997) placed at each strip door an “average” trailer containing an amount of freight for

each destination proportional to the historical flow to that destination. For each destination  $j$  they created a shipment with weight  $w_j$ , where  $w_j$  is the average weight of freight bound for destination  $j$  per incoming trailer during some historical period (typically one month). They called the resulting model the *average-trailer* model.

### 1.1 Modeling altered flows

If supervisors make assignments based on the destinations of shipments in the incoming trailers, the average-trailer model no longer describes the long run freight flow through any particular door. For example, when supervisors use a look-ahead scheduling policy, those strip doors nearest the Baltimore stack door will likely receive more Baltimore freight than those that are farther away. The average-trailer model assumes that each strip trailer receives the same amount of Baltimore freight.

To model the altered material flows that result from look-ahead scheduling, we construct *biased trailers*, which contain freight that is “biased” toward those destinations that are closest to the strip doors to which they are assigned. We construct biased trailers with the following linear program. Let

- $I$  = the set of all strip trailers,
- $J$  = the set of all destination trailers,
- $x_{ij}$  = the weight (in pounds) of freight in strip trailer  $i$  bound for destination trailer  $j$ ,
- $d_{ij}$  = the distance between trailer  $i$  and trailer  $j$ ,
- $b_j$  = the total weight of freight bound for destination trailer  $j$ ,
- $c$  = the capacity (in pounds) of a strip trailer, and
- $\xi$  = the minimum number of trailers that must contain freight for any destination.

The formulation is

$$\text{Minimize } \sum_{i \in I} \sum_{j \in J} d_{ij} x_{ij}$$

$$\text{subject to } \sum_{i \in I} x_{ij} = b_j \quad \forall j \in J \quad (1)$$

$$\sum_{j \in J} x_{ij} \leq c \quad \forall i \in I \quad (2)$$

$$x_{ij} \leq b_j/\xi \quad \forall i \in I, j \in J \quad (3)$$

$$x_{ij} \geq 0 \quad \forall i \in I, j \in J. \quad (4)$$

We define the capacity  $c$  to be the average weight of an incoming trailer. For the distances  $d_{ij}$  we use the rectilinear distance between trailers  $i$  and  $j$ , because workers and forklifts tend to travel rectilinear paths due to the aisles created by freight placed on the dock.

The weights  $b_j$  represent the total weight of freight bound for destination  $j$ , assuming that all strip doors contain an average trailer. The solution to the biased-trailer model contains the same amount of freight for each destination as the average-trailer model, only it is redistributed among the strip trailers according to the layout.

The intuition behind our model is that by assigning incoming trailers to doors based on their contents, supervisors alter the distribution of freight that passes through each strip door so that nearby stack doors receive more of the freight. The LP does this in an “optimal” way by allocating the freight to different strip doors based on their locations and the locations of nearby stack doors.

The key to understanding how the model allocates freight to trailers lies in the parameter  $\xi$ . If  $\xi$  is small, then Constraint 3 is not very restrictive, and the model is free to concentrate the freight for destination  $j$  into a few strip trailers near that destination. In the extreme case that  $\xi = 1$ , Constraint 3 is non-binding because of Constraint 1, and the solution to the LP is a lower bound (albeit, not a tight one) on actual travel cost for the layout. It represents an imaginary situation in which all incoming trailers meet and swap freight in an optimal way before they arrive at the terminal.

If  $\xi$  is large, then Constraint 3 forces  $x_{ij} \ll b_j$ , and freight for destination  $j$  must be distributed among many strip trailers. In the extreme case that



there are  $n$  strip doors and  $\xi = n$ , the solution forms precisely average trailers, because Constraints 1 and 3 lead to  $x_{ij} = (b_j/n) = w_j$ , for all strip trailers  $i$ , and there is a unique feasible solution.

## 1.2 The effects of freight mix and queue length

No matter how effective the supervisor is at assigning incoming trailers to strip doors, the freight that actually passes through a particular strip door can only be as concentrated as the trailers' contents allow. For example, in practice, not all Baltimore freight would flow through the two or three strip doors closest to the Baltimore stack door. Constraint 3 models this observation by preventing the LP from assigning too much freight for a particular destination to the strip trailers nearest its stack door.

The supervisor's ability to influence flows also depends on the length of the queue of trailers from which he makes assignments. Consider the extreme case in which the supervisor chooses from a queue of length 1. The result is FCFS scheduling, and the supervisor has no influence on freight flows. Conversely, if the queue is long, he will have greater influence because there are more trailers from which to choose, and he will make, on average, better assignments.

## 1.3 Solution method

The objective function value of the LP provides the cost for a layout. To construct a good layout, we randomly assign trailers to doors and compute the material flow cost by solving the linear program. To improve the layout, we swap a pair of trailers and solve the LP to determine the cost. If the cost improves, we keep the interchange; otherwise, we do not. We do not swap pairs of strip trailers, because doing so does not affect the cost. The algorithm continues to swap trailers until there are no improving interchanges. At each iteration, the LP is easy to solve, because after an interchange the new LP is primal-feasible. Solutions to our test problems took 20–60 minutes on an IBM RS/6000 Model 590 workstation using a C program to perform the interchanges and OSL to

solve the LPs.

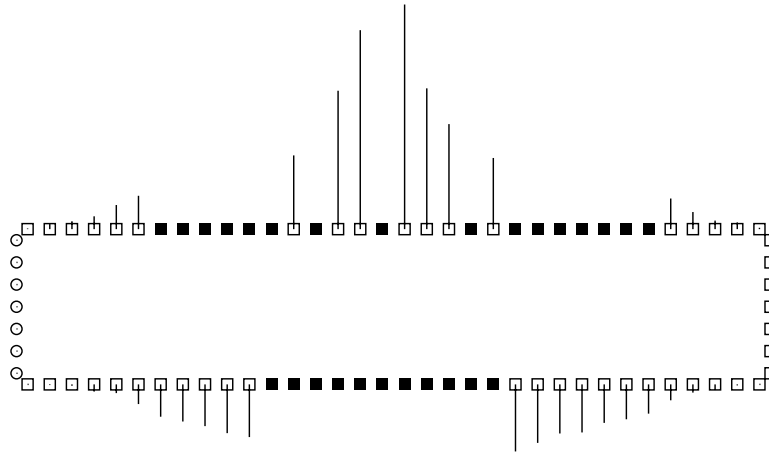
## 2 Layouts

We tested the model using data from the Atlanta terminal of a large LTL carrier. To determine the flow to each destination, we examined the freight that passed through the terminal in one month. In this sense, we did not use historical flows, but rather an instance of those flows. We chose to develop our layouts based on the instance rather than historical flows so that any deviation from average flows would not affect conclusions based on the simulations. We contend that the effects of a deviation from average flows used to develop a layout would apply to all candidate layouts, and would have a negligible effect on our results.

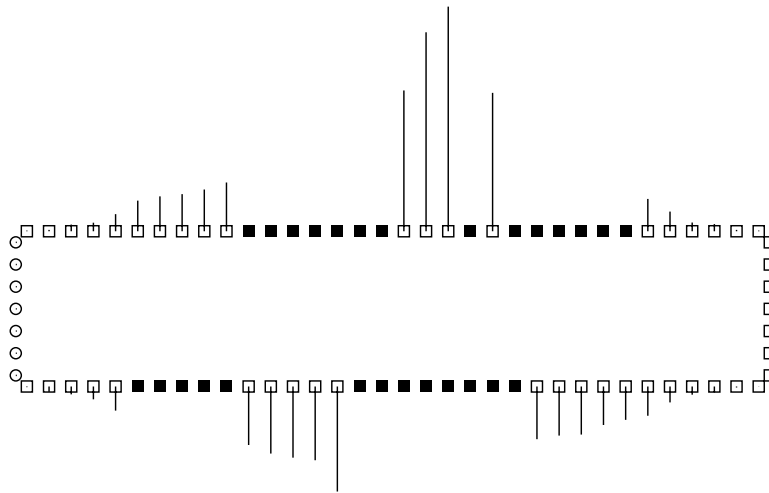
The terminal at the test site contains 27 strip doors and 48 stack doors, corresponding to as many destinations. We constructed layouts for values of the influence parameter  $\xi = 1$  through  $\xi = 27$ . To simplify the exposition, we refer to “the layout corresponding to  $\xi = 27$ ” as “Layout 27,” and so forth. Following are 6 representative layouts.

Figure 2(a) shows Layout 27. (In this and other figures, open squares correspond to stack doors and filled squares to strip doors. The line extending from an open square represents the relative total flow to the destination of that stack door. Open squares with no line represent destinations which received no freight at the test site during the test period. In fact, the small amount of freight that was received for these destinations was routed to a nearby hub terminal.) Because there are 27 strip doors and  $\xi = 27$ , this flow model is equivalent to the average-trailer model. The solution assumes that the supervisor has no influence on freight flows, and flows from all strip doors are identical. The highest flow destinations are in the center of the dock surrounded by strip doors, which form three groups.

Figure 2(b) shows Layout 21, which corresponds to the supervisor having some, but not a great deal of, influence over flows. The structure of Layout 21 is similar to that of Layout 27, except that strip doors form four groups instead



(a) Layout 27.



(b) Layout 21.

Figure 2: Layouts for low levels of supervisor influence.

of three. This is expected because as the supervisor is assumed to exert more influence on flows, those flows will become more localized.

Figures 3(a) and 3(b) illustrate layouts created with moderate values of  $\xi$ , corresponding to greater supervisor influence. In Layout 16, strip doors and the highest-flow stack doors are interspersed in the center of the dock. Layout 9 has distinct regions of high flow, one on each side and two at the opposite end of the dock. There are also fewer strip doors in the center of the dock, because the model assumes that the supervisor is able to effectively localize flows into the regions of high flow.

Figures 4(a) and 4(b) illustrate layouts created with low values of  $\xi$ , corresponding to high levels of supervisor influence. Layout 5 has high-flow stack doors evenly dispersed around the dock, but maintains the highest-flow doors in the center. Layout 1 shows little structure, but rather wide dispersion of strip doors and stack doors. This is expected because the assumed high level of influence means that the supervisor can direct most flow for any destination to the one or two strip doors nearest the destination trailer.

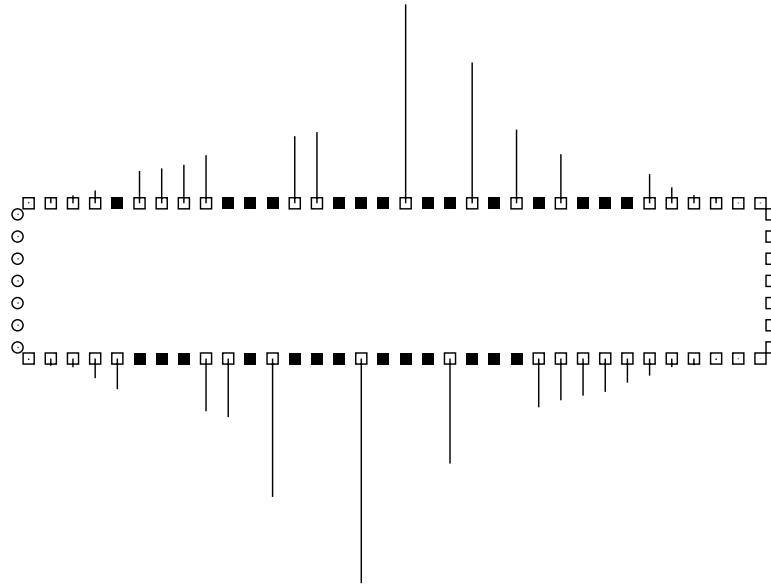
### 3 Simulation

To determine the layout with the lowest expected cost, we ran simulations of all layouts, using a look-ahead scheduling policy and trailers created based on data from 2,017 trailers unloaded at the test site. The data were collected from freight that flowed through the test site in one month.

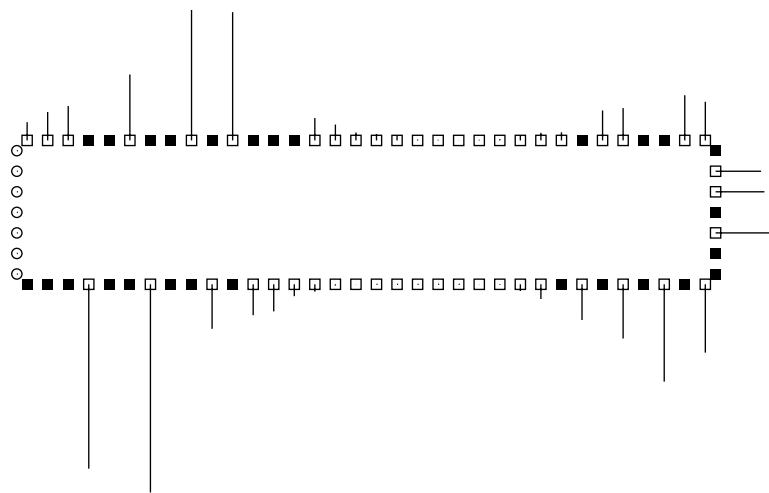
#### 3.1 Creating random trailers

A trailer contains a number of shipments, each bound for a potentially different destination and having a distinct number of pieces and total weight. Carriers in the LTL industry keep data at this level of detail, but do not record the weight of individual pieces within a shipment.

Based on the 2,017 sample trailers (containing more than 20,000 shipments),

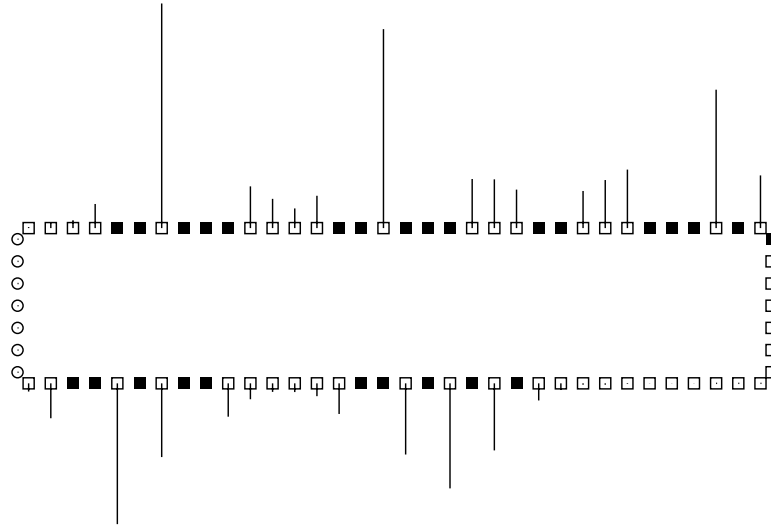


(a) Layout 16.

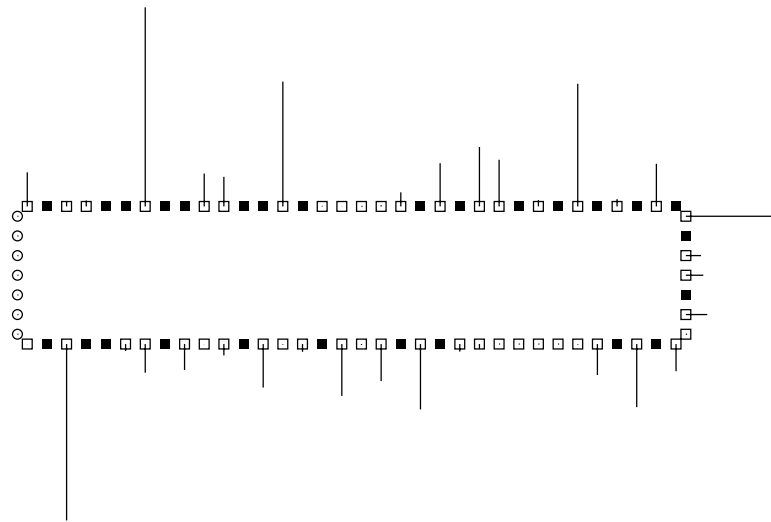


(b) Layout 9.

Figure 3: Layouts for moderate levels of supervisor influence.



(a) Layout 5.



(b) Layout 1.

Figure 4: Layouts for high levels of supervisor influence.

we created empirical distributions for the total number of shipments on a trailer, the destination of a shipment, the number of pieces in a shipment, and the weight of a shipment of  $n$  pieces. Because the weight per piece in a shipment is highly correlated with the number of pieces in the shipment (shipments with greater weight per piece have fewer pieces), we created a separate empirical distribution for every number of pieces  $n$  in a shipment.

To create a shipment we sampled for the destination and the number of pieces. Given the number of pieces, we chose the appropriate distribution and sample for the weight of the shipment. We used Algorithm 1 to generate a random trailer.

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**Algorithm 1** Generate a random trailer

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1: Sample for the total number of shipments  $T$ 
2: loop
3:   Sample from the destination distribution for dest
4:   Sample from the pieces distribution for pieces
5:   Sample from the weight distribution (with pieces pieces) for weight
6:   if (Trailer weight + weight > Capacity) or
      (Shipments on trailer =  $T$ ) then
7:     Return trailer
8:   else
9:     Add a shipment with dest, pieces, and weight
10:    Update Trailer weight and Shipments on trailer
11:  end if
12: end loop

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Because while building a trailer we may reach the weight capacity before we have added all the shipments, our random trailers have, on average, fewer shipments than actual trailers have. We observed that the random trailers had a number of shipments generally within 10% of the number on the actual trailers. The total weight of the random trailers was proportionately lower. While this introduces some bias, it does not affect the *relative* labor cost required to move

freight, when comparing different layouts.

### 3.2 Look-ahead scheduling

The most obvious scheduling rule is to assign to an open strip door that trailer in the queue having the lowest travel cost (or the lowest travel cost per unit of freight) for the open door. We chose another rule because these rules could cause particularly high-cost trailers to be stuck in the queue for a long period of time.

We used the following look-ahead scheduling rule: Let  $p_i(k)$  be the strip door providing the  $k^{\text{th}}$  lowest travel cost for incoming trailer  $i$ , and suppose that strip door  $j$  is open. The supervisor scans the queue and chooses the first trailer  $i$  such that  $p_i(1) = j$ . If none exists, he scans the queue again, looking for the first trailer such that  $p_i(2) = j$  and so on, until a trailer is selected. This scheduling rule forces high-cost trailers out of the queue, and so approximates the observed behavior that a supervisor does not unreasonably delay unloading the most difficult trailers.

### 3.3 Results

For each layout, we simulated the same arrival stream of 1000 random trailers and allowed the simulated supervisor to choose from a queue of trailers the best trailer for each open strip door. The cost of a run was the total labor cost due to travel required to move the freight from the 1000 trailers to the appropriate stack doors. We ran 20 replications to develop statistics. We repeated the experiment for queue lengths of 1, 5, 10, and 20. (Queue lengths of more than 20 are rare for an LTL terminal.) We assumed that the incoming queue was always full. (In practice, the queue for a large breakbulk terminal empties periodically, about once per week.)

To start the simulation, we randomly assigned trailers into all strip doors and began processing. We used statistics obtained from a large LTL carrier for average worker and forklift speeds and times to load and unload pieces and



pallets. Because the first set of trailers to be stripped was not assigned according to the scheduling rule, we subtracted from the final cost the cost of processing the randomly assigned trailers.

Figures 5 and 6 show the simulation results for two different queue lengths. Before discussing the results, we make a few general observations. The fact that the cost of “consecutive” layouts varies significantly for Layouts 1–12 in these figures is probably due to the fact that our flow model only approximates the tendency of a strip door to have more flow for nearby destinations; actual flows are highly dependent on the mix of freight in incoming trailers. For Layouts 1–9, the supervisor does not exert the level of influence assumed by the flow model; thus the flow model breaks down and the layouts perform unpredictably.

For all queue lengths, Layouts 13–27 performed much better than Layouts 1–12. We believe this is because Layouts 13 and following show a more “centric” structure, in which most of the high-flow stack doors are located near the center of the dock. The fact that these layouts performed better than those with local regions of high flow suggests that the freight on the sample trailers is not “separable” enough to make effective use of the local regions of high flow; rather, layouts with centrally located strip doors and high-flow destinations provide a single region where any incoming trailer can be unloaded with a reasonably low travel time.

Layouts 8 and 9 were especially poor for all queue lengths. Notably, these were the only two layouts that grouped strip doors and all the high-flow stack doors at the ends of the dock and put low-flow stack doors in the center.

Figure 5 shows the results for queue length 1, which is equivalent to FCFS scheduling. As expected, Layout 27 had the lowest average cost; but with 90% confidence it was no better than Layouts 19 and 23–26. We expected Layout 27 to have the lowest cost because it corresponds to the supervisor having no influence over material flows, which is the case under FCFS.

Figure 6 illustrates the results for queue length 10, and shows that several of the layouts constructed with the altered flows model had lower cost than Layout 27, but only marginally so. Layout 16 had the lowest average cost, and,

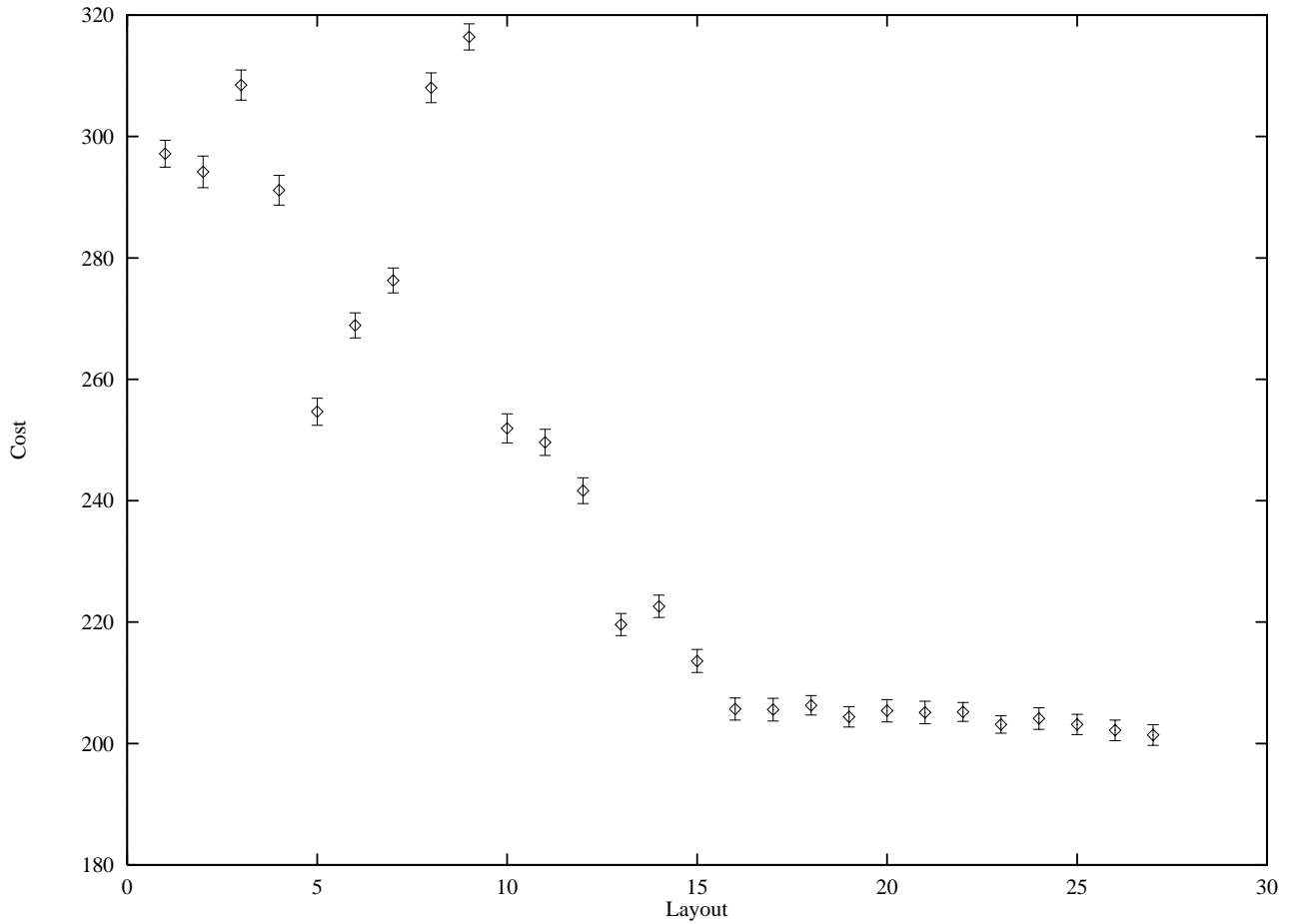


Figure 5: Simulation results for the FCFS scheduling policy. Intervals at each point represent 90% confidence intervals.

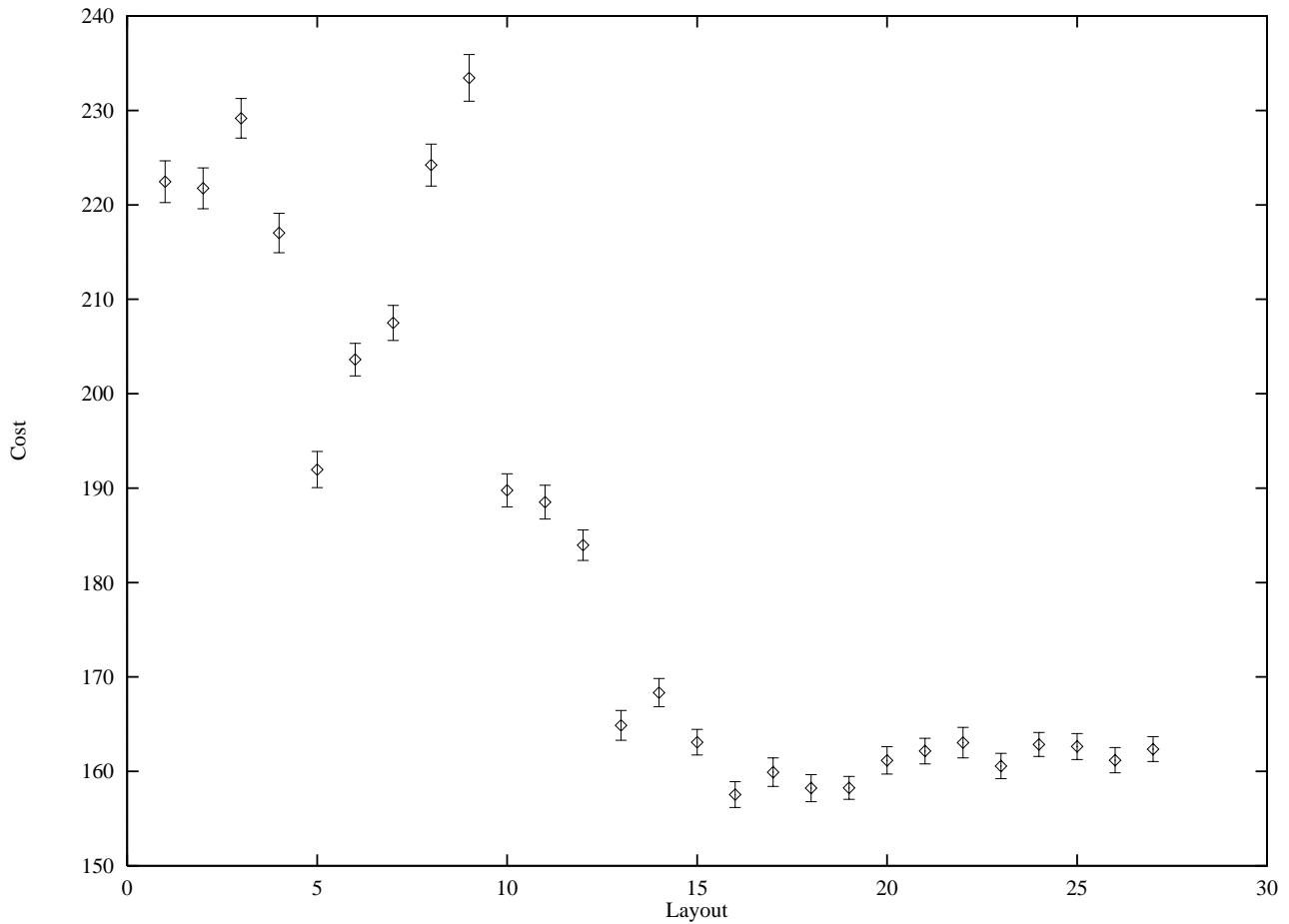


Figure 6: Simulation results for an incoming trailer queue of length 10.

with 90% confidence, was better than all layouts except Layouts 17–19. The cost for Layout 27 was still within 3.0% of the cost of Layout 16. For queue length 5 (results not shown), Layout 16 was again the lowest cost layout, but only 1.6% better than Layout 27. For queue length 20 (results also not shown), Layout 16 was 4.0% better than Layout 27. Also significant is the fact that only marginal gains seem possible when choosing from a longer queue. The costs for Layout 16 improved 5% when choosing from a queue of 10 rather than 5, and only 3% when choosing from a queue of 20 rather than 10.

While saving 3–4% in labor cost due to travel (roughly 1% of overall labor

cost in a terminal) would be welcomed by any carrier, these statistics do not suggest that substantial savings can be obtained by accounting for a look-ahead scheduling policy of supervisors. The layout constructed with the average trailer model (Layout 27) was robust for the simulation experiments.

This observation is based on data from one terminal of a single carrier, and, as we will show, should not be applied to terminals with different freight characteristics. The results do suggest, however, that designers that ignore the altered material flows of look-ahead scheduling may not be missing much, if the freight mix is similar to that in our test site.

## 4 Results for different freight mixes

We performed similar experiments with additional sets of trailer manifests, each containing trailers having shipments with fewer destinations on average than the trailers from the test site. Our objective was to determine how sensitive our results are to the mix of freight in the trailers.

We constructed the new trailers by sampling the weight and number of pieces for a shipment from the trailer data as before. When sampling for the destination of a shipment, we chose the same destination as the previous shipment with probability  $p$ ; otherwise, we sampled for a new destination. As the probability  $p$  increases, the random trailers tend to have shipments with fewer destinations. We constructed random trailer sets for  $p = \{0.6, 0.8, 1\}$ , which produced trailers with an average 3.7, 2.4, and 1 destination per trailer respectively. The trailers in the test site data contained an average 6.4 destinations per trailer.

With trailers having fewer destinations on average, the simulation results showed the benefit of using the altered flows model: Layouts 10–19 became progressively better when compared to Layout 27. Figure 7 shows the results for trailers having a single destination per trailer. For this freight mix the supervisor exerts the highest level of influence over material flows, and several of the layouts modeling altered flows are much better than the layout modeling average flows (Layout 27). Layout 16 had the lowest cost for all three values

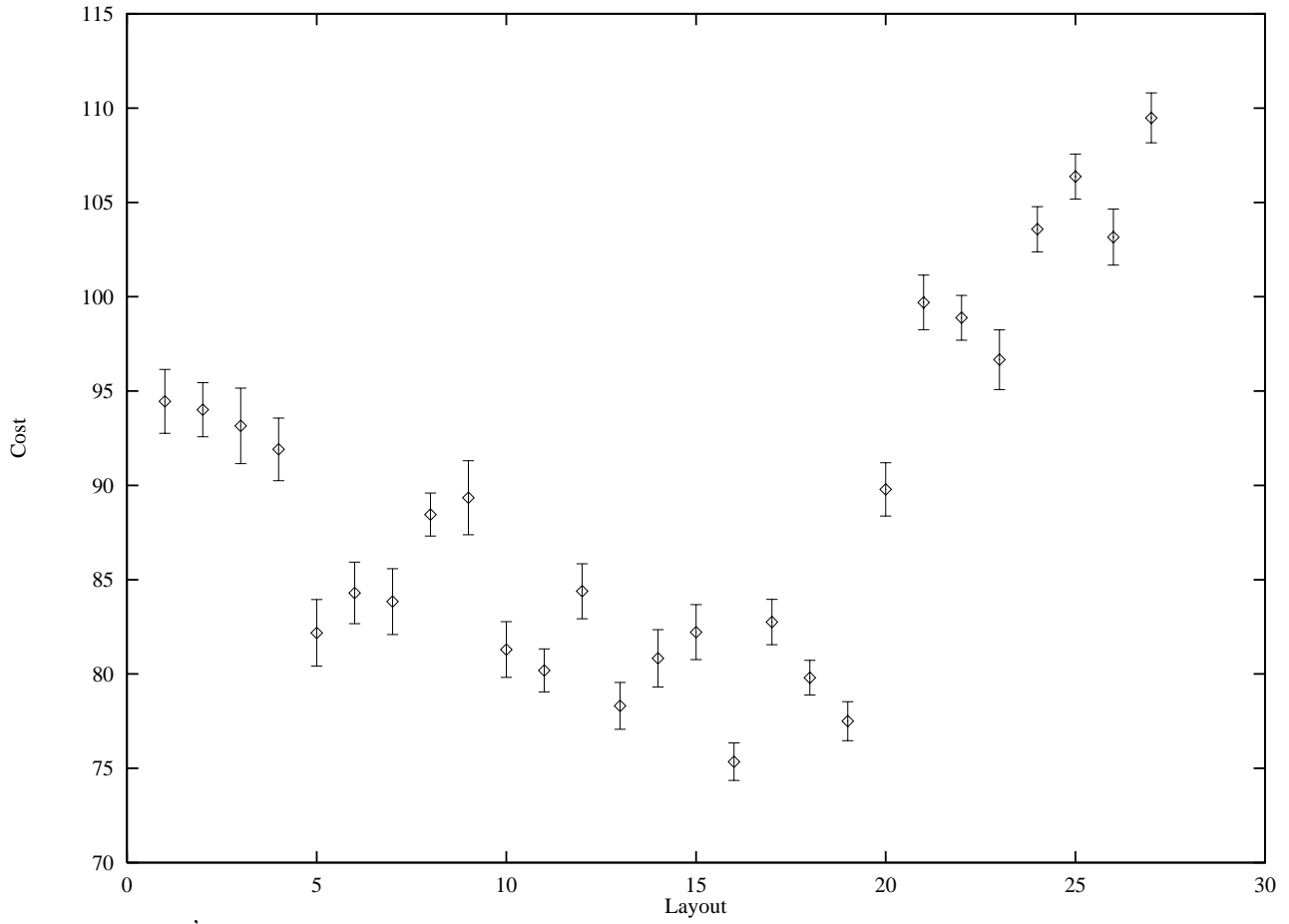


Figure 7: Simulation results for trailers containing only one destination per trailer. Trailers were chosen from a queue of length 10.

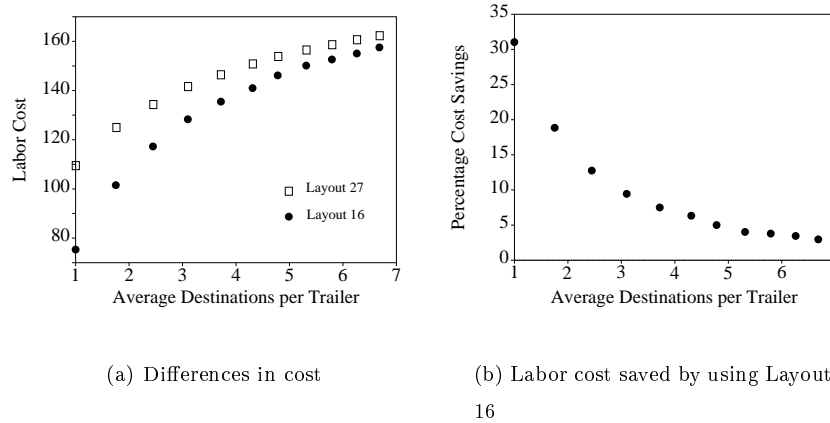


Figure 8: A comparison of Layouts 16 and 27

of  $p$ , and had cost more than 31% lower than Layout 27 when  $p = 1$ . We show the result for a single destination per trailer not because it is realistic for LTL terminals (it is not), but because it confirms that the altered flows model does exploit the look-ahead scheduling of a supervisor, when he has sufficient influence on material flows.

We compared Layouts 16 and 27 over a number of different freight mixes to illustrate the effect of the average number of destinations per trailer on average labor cost when using look-ahead scheduling and queue length 10 (see Figure 8). For the freight mix in the sample trailers, Layout 16 is only 3.0% better than Layout 27, but as the average number of destinations per trailer goes down, Layout 16 becomes more dominant. This indicates that the mix of freight on incoming trailers has a significant effect on the performance of the altered flows model.

## 5 Conclusions

Terminal managers have much to gain by having supervisors schedule incoming trailers into strip doors. Using the look-ahead algorithm we proposed, labor costs due to travel were more than 15% lower in simulation experiments when

scheduling incoming trailers into strip doors than when unloading them according to a FCFS policy. Because travel cost is approximately 15% of labor cost, terminal managers could expect approximately 2–3% reduction in total labor cost by using look-ahead scheduling.

While many supervisors are already making an effort toward this sort of scheduling, they are often doing so without decision support tools. The look-ahead algorithm we proposed could easily be incorporated into daily operations. We recognize that often assignments must be made on bases other than travel cost (to maintain the proper mix of cartons and pallets on the dock, for example), but a formal scheduling algorithm could provide valuable guidance for most assignments.

The simulations also showed that the length of the queue from which the supervisor chooses is not so significant—the total cost assuming a queue of 20 trailers was only slightly lower than the cost assuming a queue of 5 trailers. It seems rather more important to make the effort to schedule trailers than to worry about establishing the best conditions for such scheduling.

For the data from our test site, layouts constructed with the altered flows model performed only 3–4% better in simulation experiments than a layout constructed with the average-trailer model. It seems that terminals with similar freight mixes would gain only a little by using the altered flows model.

This may not be the case for other terminals. We showed that, if incoming trailers have fewer destinations per trailer, layouts constructed with the altered flows model can perform much better than a layout created with the average-trailer model. For trailers with fewer destinations on average, the supervisor has more influence over material flows, and actual flows are less like those assumed in the average-trailer model, and, presumably, more like those in the altered flows model. For trailers having an average 3.7 destinations per trailer (the trailers from the test site contained an average 6.4 destinations per trailer), the best layout developed with the altered flows model afforded a 7.5% savings in labor cost due to travel, assuming a queue of 10 trailers.

Our observations regarding the advantages of unloading trailers with fewer

destinations confirm the practice of many breakbulk terminals of requesting that origin terminals pre-sort freight by region onto multiple trailers before dispatching them to the breakbulk. One terminal we visited in Stockton, CA has an origin terminal pre-load trailers into two types: those with freight bound for the Rocky Mountain region and those with freight bound for central California. When the trailers arrive in Stockton, they are assigned to strip doors in the appropriate part of the dock.

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