Vehicle-Miles for a Freight Carrier with Two Capacity Constraints

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ABSTRACT

The amount of freight that can be fit on a vehicle depends on the vehicle's weight capacity and volume capacity. In this paper mathematical equations are developed for evaluating the impact of weight capacity and volume capacity on total vehicle-miles. It is shown that the number of vehicle loads needed to carry a large amount of material is minimized when all vehicles are filled to the same capacity constraint. This is accomplished by mixing light items with heavy items in vehicle loads. Following this policy can reduce the number of vehicle loads and vehicle-miles. Under ideal circumstances, the reduction can be as large as 50 percent. Simple equations are provided for estimating the potential reduction in vehicle loads and vehicle-miles to be realized.

The cost of transporting a large quantity of items from one location to another depends on the number of vehicle loads required to carry the material and the distance traveled per vehicle load. Decreasing either the number of loads or the distance traveled per load reduces total vehicle-miles (the total distance traveled by all vehicles) and the cost of transporting the material.

The number of vehicle loads depends on the quantity of items that can be fit on a vehicle. Typically, this quantity is determined by dividing the "capacity" of the vehicle by the "size" of each item. However, vehicle capacity and item size can be measured in more than one way. Most vehicles have both a weight capacity and a volume capacity. The vehicle is full when either capacity is reached. Depending on the type of items carried, some vehicles might be filled to the weight capacity, and others might be filled to the volume capacity (Figure 1).

In this paper equations are developed that readily show how the number of vehicle loads depends on the weight capacity and the volume capacity. These equations are used to prove that the number of vehicle loads is minimized when all vehicles are filled to the same capacity constraint (that is, all loads are filled to the weight capacity, or all loads are filled to the volume capacity). To minimize the number of loads, items that have a low density (pounds per cubic foot) must be mixed with items that have a high density in vehicle loads (Figure 2). There are several ways to mix low-density with high-density items in a vehicle load. If a supplier produces both low-density and high-density items, the different items can be loaded in the same vehicle on the loading dock. Alternatively, if different suppliers located in the same area produce low-density and high-density items, the different items can be mixed by routing vehicles by both types of suppliers. Low-density items can also be mixed with high-density items at a transportation terminal.

It is also demonstrated that standard vehicle routing methods do not minimize total vehicle-miles when some locations produce (or receive) items that have a low density and other locations produce (or receive) items that have a high density. Equations are provided to show when it is important to design modified vehicle routes that result in all vehicles being filled to the same capacity constraint.

Vehicle routing has been studied extensively during the last 25 years (1-3). For example, the vehicle routing problem (4) concerns routing a fleet of vehicles from a single terminal to a number of destinations so that travel distance is minimized and vehicle capacity constraints are not violated.

Although the vehicle routing problem is never complete (5-7) and difficult to optimize, many heuristics identify close to optimal solutions. For example, simple heuristics for solving the closely related traveling salesman problem, such as the Clarke-Wright method (8) locate solutions within about 7 percent of the optimal cost (9).
Despite the many applications of this problem, and the research invested in developing efficient routing algorithms, many industries continue to route vehicles manually. There are many reasons for this including lack of data and inability of available algorithms to account for all the important factors that influence the cost of operating vehicles.

The existence of two vehicle capacities (weight and volume) is one factor that routing heuristics do not normally consider (although computationally impractical, a second capacity can be used in some of the optimization algorithms). Most vehicle routing heuristics group stops into routes according to geographic proximity (Figure 3). Although this approach may minimize the vehicle-miles traveled per load, it does not minimize the total number of loads and total vehicle-miles. Vehicles may have to travel "out of their way" to ensure that each load carries a mixture of low-density and high-density items (Figure 4).

Although this paper is written in the context of vehicles picking up items from many different origins, the results also apply to delivering items to many destinations. The equations developed in the first section can also be used to analyze transport-
If the density of an item is less than \( d^* \), the load reaches the volume capacity before the weight capacity. Otherwise, the load reaches the weight capacity first. The ratio \( d^*/d_i \) is an adjustment factor to account for the actual weight of material that can be fit onto the vehicle, taking into account both the weight and volume capacities.

Equation 3 can be expressed as a function of a few parameters that represent average item weights and densities. First, let \( P \) be the total number of items produced per week (the summation of \( F_i \)). Let a "light" item be an item with a density less than \( d^* \) and a "heavy" item be an item with a density greater than \( d^* \). Also let \( L \) be the set of light items, \( H \) be the set of heavy items, and

\[
p = \text{proportion of items that are light} = \frac{\sum F_i w_i}{\sum F_i} \quad i \in L
\]

\[
w_1 = \text{average weight of the light items} = \frac{\sum F_i w_i}{\sum F_i} \quad i \in L
\]

\[
d_1 = \text{average density of the light items} = \frac{\sum F_i w_i}{\sum F_i} \quad i \in L
\]

\[
w_h = \text{average weight of the heavy items} = \frac{\sum F_i w_i}{\sum F_i} \quad i \in H
\]

Equation 3 can now be written as

\[
T = \left( \frac{P}{C_w} \right) \left[ (w_1 P/d_1) + w_h (1-p) \right]
\]

Letting \( W \) be the average weight of all items \( W = \sum F_i w_i \), Equation 4 becomes

\[
T = \left( \frac{P w_1}{C_w} \right) \left[ 1 + \left( \frac{w_1 P (d^*-d_1)}{w_h} \right) \right]
\]

Equation 5 can be reduced further by introducing two new composite variables. Let

\[
P = \text{proportion of weight produced per week that is composed of light items} = \frac{w_1 P}{W} \quad i \in L
\]

\[
r = \text{ratio of the average material density of the light items to } d^* = \frac{d_1}{d^*}
\]

The minimum number of vehicle loads required per week can now be expressed as a function of just five parameters:

\[
T = \left( \frac{P w_1}{C_w} \right) \left[ 1 + \left( \frac{P (1-r)}{r} \right) \right]
\]

\( P \) and \( r \) must both be less than one and greater than zero. They must also satisfy the following inequality:

\[
d = \left( \frac{W}{v_1 P} + v_h (1-p) \right) < \frac{W}{v_1 P} = \frac{w_1 v_1}{w_h v_1} \quad \text{for } d < d_1/P
\]

\[
\text{when } d > d^*, \quad d^* < d < d_1/P \quad \text{in terms of } r \quad \text{and } P,
\]

\[
P < r \quad \text{if } d > d^*
\]

\[
\text{If } d < d^*, \quad P \text{ and } r \text{ are only constrained to be between zero and one.}
\]

Returning to Equation 6, the first term gives the number of vehicle loads when accounting for the weight capacity alone. The second term is an adjustment factor that specifies the additional number of loads when accounting for both weight capacity and volume capacity. Notice that the adjustment factor must always be greater than one, and that it increases as the proportion of weight composed of light items \( P \) increases, and increases as the average density of light items \( d^* \) decreases.

**LOADS CONTAINING DIFFERENT ITEMS**

Suppose now that vehicles carry different types of items with different weights and densities. Then the number of vehicle loads \( T \) is minimized when all loads are filled to the same capacity constraint. That is, all loads are filled to the weight capacity, or all loads are filled to the volume capacity.

This statement can be proved by contradiction. Suppose that one load contains light items and is filled to the volume capacity and another load contains heavy items and is filled to the weight capacity. Then any arbitrary proportion of material can be exchanged between the two loads without violating a capacity constraint.

Let \( w_1, w_2, v_1 \), and \( v_2 \) be the respective weights and volumes of the light and heavy loads, where \( w_1 < C_w \), \( v_1 = C_v \), \( w_2 = C_w \), and \( v_2 < C_v \). Let the circumflex (') denote the weight or volume of a load after a proportion \( (q) \) of material is exchanged between loads. Then

\[
\hat{w}_1 = w_1 (1-q) + w_2 q \quad \hat{v}_1 = v_1 (1-q) + v_2 q
\]

\[
\hat{w}_2 = w_2 (1-q) + w_1 q \quad \hat{v}_2 = v_2 (1-q) + v_1 q
\]

which can also be written as

\[
\hat{w}_1 = w_2 - (w_2 - w_1) (1-q) \quad \hat{v}_1 = v_1 - (v_1 - v_2) q \quad \hat{w}_2 = w_2 - (w_2 - w_1) q \quad \hat{v}_2 = v_2 - (v_1 - v_2) (1-q)
\]

Notice that exchanging any proportion \( (q) \) of material between the two loads reduces the weight and volume of both loads below the respective capacities. Therefore, a necessary condition for minimizing \( T \) is that all loads be filled to the same capacity constraint.

To minimize \( T \) it is not necessary that all loads carry exactly the same mix of different items or carry exactly the same weight and volume of material. For example, if all loads are filled to the volume capacity, it does not matter how much weight of material is loaded onto each vehicle. Thus the statement that all loads are filled to the same capacity constraint is both a necessary and a sufficient condition for minimizing \( T \).

**SAVINGS FROM COMBINING DIFFERENT ITEMS IN VEHICLE LOADS**

Whenever light items \( (d_i < d^*) \) are shipped in separate vehicles than heavy items \( (d_1 > d^*) \), as is the case when vehicles contain only one type of item, the number of loads is given by Equation 6. Combining light with heavy items in vehicle loads always results in decreased loads. Let \( T^* \) denote the number of loads when all vehicles are filled to the same capacity constraint (that is, when \( T \) is minimized). Then

\[
T^* = \text{Fmax} \left\{ \left[ \frac{V}{C_w}, \left( \frac{w_1 v_1}{w_h v_1} \right) \right] \right\} = \left( \frac{P w_1}{C_w} \right) \left( \max \left( \frac{d^*}{d}, 1 \right) \right)
\]

where \( V \) is average volume of all items and \( d \) is average density of all items \( (w/V) \).
The first term of Equation 10 gives the number of loads when accounting for weight capacity alone, and the second term is an adjustment factor that specifies the additional number of loads when accounting for both capacities. If \( d^*/d \) is greater than one, all vehicles are filled to the volume capacity and the adjustment factor equals \( d^*/d \). Otherwise, all vehicles are filled to the weight capacity and the adjustment factor equals one. Therefore the adjustment factor is greater than or equal to one.

\[ T/T^* = \begin{cases} 1 + P(l-r)/r & \text{for } d > d^* \\ (d/d^*)[1 + P(l-r)/r] & \text{otherwise} \end{cases} \]  

Equation 11 can be used to estimate quickly the maximum reduction in vehicle loads from filling all vehicles to the same capacity constraint.

Recall that \( P \) must be less than \( r \) when \( d/d^* \) is greater than one. Equation 11a is maximized when \( P \) equals \( r \). Therefore substituting \( P \) for \( r \) in Equation 11a,

\[ T/T^* < 2 - P \text{ for } d > d^* \]  

As a function of \( P \), \( T/T^* \) approaches two as \( P \) approaches zero, and approaches one as \( P \) approaches one. Therefore the adjustment factor is greater than or equal to one.

The parts produced by one city contain many different companies engaged in the same industry. For instance, one region may contain a large concentration of plastic companies, and another may contain a large concentration of fastener (nuts and bolts) manufacturers. If vehicles are routed on the basis of geographic proximity alone, all the vehicles in the fastener region would be filled to volume capacity, resulting in as many as twice as many loads as necessary.

Figure 6 shows a situation in which manufacturers in one city produce light items and manufacturers in another city produce heavy items. A fleet of vehicles picks up items at these two cities and delivers them to a common destination. If routed on proximity alone, each vehicle would visit only one of the two cities. However, to minimize the total number of loads and fill the vehicle to volume capacity, the parts produced by the other three suppliers have large densities and fill the vehicle to weight capacity.

If each supplier shipped independently of the others, 10.86 truckloads, on average, would be needed per week. However, if the different parts were combined in the same vehicles, so that all vehicles were filled to the volume capacity, the number of truckloads would be reduced to only 7.96 per week (a reduction of 27 percent). Equation 11a predicts that the ratio of \( T \) to \( T^* \) should equal 1.36 for this example, which exactly matches the ratio of 10.86 to 7.96.

**TABLE 1 Example Part Data**

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Part</th>
<th>Weight (lb)</th>
<th>Volume (ft(^3))</th>
<th>Production Rate (parts/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1</td>
<td>Part A</td>
<td>1.0</td>
<td>1.0</td>
<td>1,000</td>
</tr>
<tr>
<td>Supplier 1</td>
<td>Part B</td>
<td>0.5</td>
<td>0.4</td>
<td>2,000</td>
</tr>
<tr>
<td>Supplier 1</td>
<td>Part C</td>
<td>0.8</td>
<td>0.2</td>
<td>1,000</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>Part D</td>
<td>10.0</td>
<td>0.2</td>
<td>5,000</td>
</tr>
<tr>
<td>Supplier 3</td>
<td>Part E</td>
<td>0.1</td>
<td>0.01</td>
<td>50,000</td>
</tr>
<tr>
<td>Supplier 3</td>
<td>Part F</td>
<td>0.2</td>
<td>0.005</td>
<td>50,000</td>
</tr>
<tr>
<td>Supplier 3</td>
<td>Part G</td>
<td>5.0</td>
<td>0.1</td>
<td>50,000</td>
</tr>
<tr>
<td>Supplier 3</td>
<td>Part H</td>
<td>0.4</td>
<td>0.01</td>
<td>50,000</td>
</tr>
<tr>
<td>Supplier 4</td>
<td>Part I</td>
<td>5.0</td>
<td>10.0</td>
<td>1,500</td>
</tr>
<tr>
<td>Supplier 4</td>
<td>Part J</td>
<td>5.0</td>
<td>10.0</td>
<td>500</td>
</tr>
<tr>
<td>Supplier 5</td>
<td>Part K</td>
<td>2.0</td>
<td>0.1</td>
<td>10,000</td>
</tr>
</tbody>
</table>

**TABLE 2 Summary Data**

<table>
<thead>
<tr>
<th>Supplier 1</th>
<th>Production Rate</th>
<th>Average Density</th>
<th>Trucks per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1</td>
<td>2,800 lb/week</td>
<td>2,000 ft(^3)/week</td>
<td>0.53</td>
</tr>
<tr>
<td>Supplier 1</td>
<td>50,000 lb/week</td>
<td>1,000 ft(^3)/week</td>
<td>50.0</td>
</tr>
<tr>
<td>Supplier 1</td>
<td>285,000 lb/week</td>
<td>2,000 ft(^3)/week</td>
<td>50.0</td>
</tr>
<tr>
<td>Supplier 1</td>
<td>10,000 lb/week</td>
<td>20,000 ft(^3)/week</td>
<td>0.5</td>
</tr>
<tr>
<td>Supplier 1</td>
<td>20,000 lb/week</td>
<td>1,000 ft(^3)/week</td>
<td>20.0</td>
</tr>
</tbody>
</table>

**MODIFYING ROUTES TO REDUCE NUMBER OF LOADS**

Most vehicle routing heuristics group stops into routes according to geographic proximity and do not necessarily minimize total vehicle-miles (8,10,11). It is not unusual for geographic regions to contain many different companies engaged in the same industry. For instance, one region may contain a large concentration of plastic companies, and another may contain a large concentration of fastener (nuts and bolts) manufacturers. If vehicles are routed on the basis of geographic proximity alone, all the vehicles in the plastics region would be filled to volume capacity, and all the vehicles in the fastener region would be filled to weight capacity, resulting in as many as twice as many loads as necessary.
ensure that all vehicles are filled to the same capacity constraint) vehicles must be routed through both cities.

The total distance traveled on a vehicle route includes the local distance traveled to pick up items within the two cities and the line-haul distance between the cities and the destination. The local distance depends on the total number of stops and the stop density [e.g., stops per square mile (12,13)]. Assuming that the two cities do not overlap, the local distance is nearly independent of whether all vehicles visit both cities or just one. Therefore only the line-haul distance is considered in the following analysis.

The following equations apply to the situation in which \( d > d^* \). Following the same approach, it is not difficult to derive similar equations for the case where \( d < d^* \). Let

\[
D_1 = \text{distance from city producing light items to the destination (miles)},
\]

\[
D_2 = \text{distance from city producing heavy items to the destination (miles)},
\]

\[
D_3 = \text{distance between the two cities (miles)}.
\]

Assume initially that all vehicles return empty from the destination. Then, if all vehicles visit only one city, the number of vehicle-miles traveled per week (\( L_1 \)) is

\[
L_1 = \frac{(FW/CW)}{2} \left[ \frac{D_1}{P/r} + \frac{D_2}{(1-P)} \right]
\]

(13)

Alternatively, if all vehicles visit both cities, the number of vehicle-miles is

\[
L_2 = \frac{(FW/CW)}{2} (D_1 + D_2 + D_3) \quad \text{if } d > d^*
\]

(14)

It is not necessary for all vehicles to visit both cities to minimize T. However, if \( d > d^* \), all vehicles visiting the "light" city must also visit the "heavy" city, and, if \( d < d^* \), all vehicles visiting the "heavy" city must also visit the "light" city. Equation 14 is an upper bound on total vehicle-miles with this type of coordination. Exact calculation of total vehicle-miles is not complicated, but it does require detailed information on the densities of all items. Therefore this calculation will not be performed.

The ratio of \( L_1 \) to \( L_2 \) is

\[
\frac{L_1}{L_2} = \frac{(2D_1(P/r) + D_2(1-P))}{(D_1 + D_2 + D_3)} \quad \text{if } d > d^*
\]

(15)

If \( L_1/L_2 \) is greater than one, it is better to route all vehicles through both cities than through just one. This ratio ranges from zero (e.g., when \( D_2 = 0 \) and \( P = 0 \)) to two (when \( D_1 = 0 \), \( P = r \), and \( r = 0 \)). Therefore routing all vehicles through both cities can reduce total vehicle-miles by as much as 50 percent.

SPECIAL CASE: \( D_2 = D_1 + D_3 \)

To facilitate interpreting Equation 15, two special cases will be examined. This section examines the case in which \( D_2 = D_1 + D_3 \) (that is, the destination and the two cities fall on a line and the "heavy" city is farther from the destination than the "light" city). For this special case, the number of vehicle loads is minimized when all vehicles visit the "heavy" city, and Equation 15 is exact. In the following section the case in which \( D_1 = D_2 \) (that is, the two cities are the same distance from the destination) will be examined. All of the following equations assume that \( d > d^* \).

When \( D_2 = D_1 + D_3 \), Equation 15 can be reduced by substituting \( D_2 - D_1 \) for \( D_3 \):

\[
\frac{L_1}{L_2} = \frac{(2D_1(P/r) + D_2(1-P))}{2D_2} \quad \text{if } D_2 = D_1 + D_3
\]

(16)

Because the \( 2s \) cancel out in Equation 16, \( L_1/L_2 \) is the same whether or not vehicles must return empty from the destination.

Let \( K \) equal the ratio of \( D_1 \) to \( D_2 \) (\( K = D_1/D_2 \)). \( K \) must be between zero and one. Then

\[
\frac{L_1}{L_2} = \frac{K(P/r)}{(1-P)} \quad \text{if } D_2 = D_1 + D_3
\]

(17)

Because \( P \) must be smaller than \( r \), and \( K \) must be less than one, \( L_1/L_2 \) must be less than or equal to two. Figure 7 shows plots of \( L_1/L_2 \) as a function of \( P \) and \( r \), for a value of \( r = 0.5 \). Notice that this ratio increases as \( K \) increases. When \( K \) is greater than \( r \),
L_1/L_2 also increases as P increases, but when K is less than r, L_1/L_2 decreases as P increases. Therefore it is most important to route vehicles through both cities when K is large and a large portion of weight produced per week is composed of light items (provided that K > r). The ratio also increases as r decreases. Therefore it is more important to route vehicles through both cities when the average density of light items is small than when it is large.

The breakeven point between routing vehicles through both cities and routing through just one occurs when L_1/L_2 = 1.

\[
1 = K(P/r) + (1-P) \quad \text{if} \quad D_2 = D_1 + D_3
\]

or, more simply, when

\[
K = r \quad \text{if} \quad D_2 = D_1 + D_3. \quad (18)
\]

When r is less than K, it is better to route all vehicles through both cities than through just one. For example, if the average density of items produced in the "light" city is one-half of the density of items (r = 0.5), vehicles should be routed through both cities when K is greater than 0.5; that is, the "heavy" city is less than twice as far from the destination as the "light" city. Because K approaches zero when r approaches zero, it can still be worthwhile to route all vehicles through both cities when the two cities are far apart.

SPECIAL CASE: D_1 = D_2

For the special case in which D_1 = D_2, the two cities are the same distance from the destination. For this special case, it may not be necessary to route all vehicles through both cities to minimize the number of vehicle loads. Therefore L_2 gives an upper bound on total vehicle-miles when the number of loads is minimized. Let D = D_1 = D_2. Then Equation 15 becomes

\[
L_1/L_2 = 2D(P/r + (1-P))/(2D + D_3) \quad (19)
\]

The breakeven point between routing all vehicles through both cities and routing all vehicles through just one city occurs when Equation 19 equals one. That is, when

\[
(2D + D_3)/2D = 1 + P/(1-r)/r \quad (20)
\]

Notice that the left side of Equation 20 is the ratio of vehicle-miles per route when vehicles visit both cities, to vehicle-miles per route when vehicle visit just one city. The right side of Equation 20 is the ratio of the number of vehicle loads when vehicles visit both cities, to the number of vehicle loads when vehicles visit just one city. Let D be the vehicle-miles per route when vehicles visit both cities and D_0 be the vehicle-miles per route when vehicles visit just one city. Then Equation 20 can be rewritten as

\[
D_0/D_0 = 1 + P/(1-r)/r \quad (21)
\]

When D_0/D_0 is less than the right side of Equation 21, fewer total vehicle-miles are required when vehicles visit both cities than when they visit just one. Otherwise, total vehicle-miles are minimized when vehicles visit just one city.

Notice that the right side of Equation 21 is identical to the right side of Equation 11a, which is plotted in Figure 3. Therefore the breakeven point between routing vehicles through both cities and routing vehicles through just one increases as P increases and r decreases.

Equation 21 also applies when vehicles do not return empty from the destination. D_0 would then be D + D_3 (the length of two legs of the route) and D_2 would then be D. For any given D and D_3, this ratio is larger when vehicles do not return empty than when vehicles do return empty. Therefore it is less advantageous to route vehicles through both cities when they do not have to return empty from the destination than when they do have to return empty from the destination.

Equation 19, which gives the ratio L_1 to L_2, can also be expressed as a function of D_0/D_0:

\[
L_1/L_2 = (D_0/D_0) [1 + P/(1-r)/r] \quad (22)
\]

Equation 22 is identical to the right side of Equation 11a (plotted in Figure 3), except that Equation 22 is multiplied by the factor D_0/D_0. If the two cities are in opposite directions from the destination, D_0/D_0 can be as small as 0.5, and L_1/L_2 would range between 0.5 and one (i.e., it would always be better to route vehicles through one city than two). D_0/D_0 can be as large as one if the two cities are located at the same place, in which case L_1/L_2 would range from one to two (i.e., it would always be better to route vehicles through both cities than through just one).

SUMMARY

The impact of weight capacity and volume capacity on total vehicle-miles has been discussed. It has been shown that the number of vehicle loads is minimized when all vehicles are filled to the same capacity constraint (that is, all vehicles are filled to the weight capacity or all vehicles are filled to the volume capacity). This may be accomplished by mixing heavy items and light items in vehicle loads.

Combining light items with heavy items in vehicle loads was shown to reduce the number of loads and vehicle-miles by as much as 50 percent. The exact reduction depends on two parameters. When the number of loads is minimized by filling all vehicles to the weight capacity, these parameters are (a) the ratio of the density of light items to the density of material that simultaneously fills vehicles to both the weight and volume capacities and (b) the proportion of weight produced per week that is composed of light items (P). A similar equation results when the number of loads is minimized by filling all vehicles to the volume capacity.

It has also been shown that commonly used heuristics for routing vehicles can obtain solutions that are far from optimal when light items and heavy items are produced in geographically separated regions. Most heuristics group stops into routes according to geographic proximity. Although this may minimize vehicle-miles traveled per route, it does not minimize total vehicle-miles. If vehicle routes are designed to ensure that all vehicles are filled to the same capacity constraint, the number of vehicle loads (and vehicle-miles) can be reduced by as much as 50 percent.

Considerable effort has been expended in the last 25 years to improve the efficiency and effectiveness of algorithms designed to solve the vehicle routing problem. However, even straightforward heuristic (such as the Clarke-Wright method), can generally obtain solutions within 7 percent of the optimum of the vehicle routing problem. The evidence provided in this paper indicates that the savings from accounting for two capacity constraints can well exceed 7 percent.
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Urban Freight Practice—An Evaluation of Selected Examples

PHILIP A. HABIB

ABSTRACT

A diverse group of urban goods movement projects and actions taken by municipalities are documented and the principal lesson or lessons derived from each project are highlighted. The research used the literature, field visits, interviews, and independent research to formulate the presentation of the selected examples. The paper contains eight examples of municipalities that have implemented projects in curb space management, off-street facility planning, and zoning. Six examples are drawn from U.S. cities and two from Canada. An evaluation follows each example to highlight the positive and negative results of each as they might affect application elsewhere. This paper is drawn from research sponsored by the UMTA University Research Program and was conducted by the author while at the Polytechnic Institute of New York.

This paper provides a detailed review of a selected number of actions taken by various municipalities to address urban freight transportation. The documentation for several of these actions included field trips and interviews. The literature, plus the author's personal knowledge or involvement, provided the documentation on the other actions.

The urban transportation planner's or the engineer's justifiable preoccupation with the need to optimize the transportation infrastructure to move people has, to date, left a wide gap in professional skills necessary to foster successful urban freight project development and evaluation. The ability to draw on the work and experiences of similar projects has not only markedly facilitated people-transportation project development but has also provided...