data base has been established, a comprehensive analytical capability has been developed, and a new demand model based on a 1976 data set has been calibrated. Preliminary results indicate that sensitivity to fare has decreased considerably since 1972, that service frequency is more significant, and that sensitivity to travel time has increased slightly.

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Analysis of Truck Deliveries in a Small Business District

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The nature of goods deliveries in a small commercial district in Pittsburgh was analyzed. The considerations in choice of the site were the expected cooperation from merchants, the diversity of store types available for analysis, and a high level of business activity. The surveys collected data on several aspects of the delivery process and its relationship to related activities in two phases. The first phase involved interviews at 59 stores in two blocks of the study site. The second phase involved recording truck pickup-and-delivery movements for one week in each block. The 400 observations covered the 8 a.m. to 12 n. period each day. The distributions in the data identified such things as hourly and daily delivery patterns, delivery times, and total number of deliveries to particular stores. Multiple linear regression was performed on the business data to test for equations that could predict the average number of deliveries per week. Regression on the movement-survey data was performed to test equations with the handling time of deliveries as the dependent variable.

Only recently has the urban goods-movement problem received a significant amount of attention from transportation planners. However, since 1970 interest in the question has increased, and it is now considered an integral part of the urban picture.

The object of this study was to identify and formulate the character of urban goods movement in a typical small commercial district. Specifically, the analysis was to

1. Validate and calibrate or refute the existing models that are designed to forecast the demands for goods movement that are associated with various categories of business establishments;
2. Collect and form the data base that is needed to study goods movement in a small urban business district made up primarily of single private owners; and
3. Analyze truck delivery and pickup patterns, including arrival and departure times, handling and dwell times, at-vehicle times, means of transporting goods, parking situations, and internal handling methods.

METHODOLOGY

Two of the primary considerations in the selection of the site were (a) the amount of cooperation anticipated from the businessmen in the area and (b) the inclusion of a typical variety of stores in a suitable district.

The Squirrel Hill business area of Pittsburgh was chosen because one of its two major streets was scheduled for renovation. Many of the local businessmen

were concerned that goods delivery service during this period could not be maintained. It was felt that one of the primary considerations in site selection, that of business cooperation, could be met because of this impending problem. In addition, the Squirrel Hill business district includes a typical variety of stores suitable for the study. At the beginning of the study, an agreement of cooperation in carrying out the study and a joint letter to the businessmen was prepared in conjunction with the local merchant's organization.

The data collection was accomplished in two steps. First, a business survey was developed to obtain information about a sample of at least 50 percent of the stores that were observed in the movement survey. The data in the first section of the business survey were determined without asking the store manager. The information included address, type of store, and products sold. It also included the location of the store in terms of distance to traffic signals and type of road, to obtain information about the impacts on traffic of goods movements.

The second section of the business survey required an interview. It was composed to obtain as much information as possible in less than 10 min; to make the answers easy to understand and reliable; and to be not too detailed or confidential, which might interfere with the cooperation of the businessmen. This section included information about floor space and number of employees and was used to correlate numbers of generated trips with the structures of the stores. As other studies have shown, it is difficult to obtain data on inventory turnovers (4). Therefore, the survey asked for the number of sales per day, which is equivalent to customers served.

All but one or two of the businessmen agreed to allow observation of the deliveries that they received. Overall, they were very cooperative and provided more information than was asked for in the survey.

The second step in the data collection was a movement survey that was developed to gather information from interviews of truck drivers and through observation of the pickup and delivery processes. As with the business survey, cooperation was generally good.

The data were collected between 8 a.m. and 12 noon. From the business-survey questionnaire, it was concluded that about 80 percent of the deliveries and pickups in the study site could be observed during those hours. The information collected included parking locations, delivery times, goods delivered, delivery-process used, and general truck-route details.

ANALYSIS OF BUSINESS SURVEY

A sample of 59 business establishments was taken on two streets. This included 15 clothing stores, primarily on Forbes Avenue, and 14 retail food stores, primarily on Murray Avenue. Figure 1 shows the distribution of answers to six of the interview questions. The bar graphs compare the characteristics of all stores with those of clothing and retail food stores.

More than 50 percent of the establishments have only one entrance, which is also used for deliveries, and almost all of them (97 percent) have no loading docks. There are some side doors (28 percent of all stores), with retail stores having a higher percentage (43 percent), but few of them are used for deliveries.

The floor-space distribution shows that most of the establishments are small to medium sized, which means that they have less than 372 m^2 (4000 ft^2) of business space. Ninety-five percent of the retail food stores were this size, while clothing stores tended to be larger.

Quite a few of the clothing stores have more than 15 salespersons, while the retail food stores are generally small family-type establishments with fewer than five employees. Almost 30 percent have only the owner and one helper to run the store. On the whole, small stores are commonest. This is also confirmed by the distribution of sales per day. The fifth bar diagram, which indicates the number of enterprises ordered from, shows that most of the stores order from more than 20 different suppliers. This is particularly true for clothing stores. Only 13 percent of them order from fewer than five different suppliers. These are either highly specialized firms, such as a fur store, or branch-store boutiques, which obtain their goods from the main stores. The number of food stores in this low category is also significant. These stores are typically delicatessens, meat markets, and other specialized small places without an extensive variety of different products.

The distribution of deliveries per week was similar for the three categories of all stores, clothing stores, and retail food stores.

Because graphic illustration alone is inadequate to establish the store characteristics that determine the nature of related goods movements, regression analysis was performed on the complete set of business data and then on a data subset that included only businesses that sell at least two different types of products. This second set of regressions was performed to test the conclusions of a similar study conducted at the Polytechnic Institute of New York (PINY) (1). The dependent variable for all regressions was the average number of deliveries per week.

The table below shows the correlations of a number of variables for the complete data set.

Dependent Variable	Weekly Deliveries (NW)
Number of product types sold (PN)	-0.1634
Number of enterprises delivering (EN)	0.1420
Floor space (000 ft^2) (FL)	0.2883
Full-time employees (EMF)	0.5434
Part-time employees (EMP)	0.1509
Total employees (TEMP)	0.5525

The strongest correlation is that between the number of employees and the number of weekly deliveries. The only apparent anomaly is the negative correlation between the number of products (referred to in the PINY report as the specialization index) and the number of weekly deliveries. This may be representative of the high number of deliveries associated with food stores and restaurants, which deal in only one type of product.

The best regression equation developed for all businesses was the following:

$$NW = 0.187EN - 0.888PN + 1.04FL + 0.471EMF + 0.738EMP \quad (1)$$

The explained sum of squares for this equation is 0.64. (These equations were developed for U.S. customary units; therefore SI units are not given for the variables.) An equation with equivalent performance for the explained sum of squares is the following:

$$NW = 0.21EN + 0.58TEMP \quad (2)$$

This equation, however, did not perform as well on the chi-squared normality test.

The PINY equation for stores selling more than one type of product had the following form:

$$NW = 9.0PN - 16.6 \quad (PN \geq 2) \quad (3)$$

but an equation of this form failed to explain the Pittsburgh data. On the other hand, an equation similar to

Equation 1 performed even better than it did for the full data set. For the data subset, the best equation was as follows:

$$NW = 0.438EN + 1.89PN - 6.82FL + 1.11EMF + 0.534EMP \quad (PN \geq 2) \tag{4}$$

The explained sum of squares for this equation is 0.83 and the chi-squared value for nine degrees of freedom was 5.76.

ANALYSIS OF MOVEMENT SURVEY

The daily patterns of deliveries and vehicle stops are shown in Figure 2. On Forbes Avenue there was a rather regular distribution on Monday through Wednesday, a slight increase on Thursday, and a peak on Friday. From an average of 48 deliveries/d at the beginning of the week, there was a 35 percent increase on Thursday and a 55 percent increase on Friday. The distribution of vehicle stops was more homogeneous, with an increase of 37 percent on Thursday and of 31 percent on Friday. A large percentage of the additional deliveries were made by the United Parcel Service (UPS) truck.

Murray Avenue did not show such a significant number of multiple deliveries. Monday, Wednesday, and Thursday are rather similar days on Murray, while Tuesday is the least busy and Friday the most busy day. Here there was an increase of about 40 percent for Fridays, which is different from the 5 percent average increase observed in Brooklyn for Thursdays and Fridays (1) and the uniformly distributed deliveries in the German town of Braunschweig (2, 3).

There was a peak period for deliveries after 10 a.m., which is comparable to the 10 to 12 a.m. peak in Brooklyn. A distinct difference between food deliveries and other deliveries is that food deliveries are more frequently made in the early hours.

There are some obvious differences in the dwelling, delivery, at-vehicle, and delay times between food stores and clothing stores (Figure 3). The average dwelling time for food stores (19.8 min) is close to the Brooklyn value of 22 min. The 33.5-min average dwelling time for clothing stores, however, is misleading, because the UPS truck makes multiple deliveries from the same curb space.

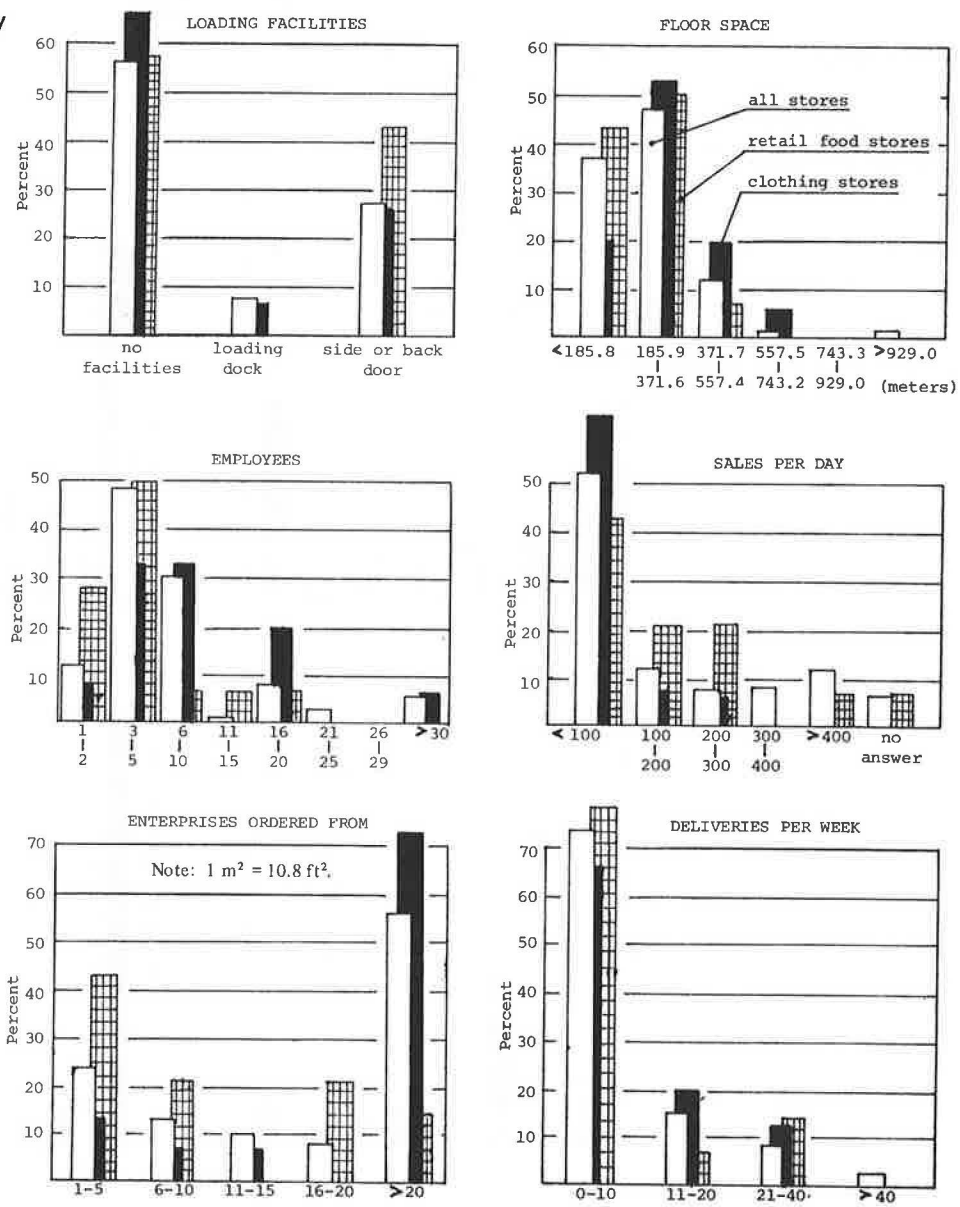


Figure 1. Distribution of business-survey responses.

The delivery times represent a more realistic impression. The unloading of trucks with food usually took longer than that of any other commodity. The reasons for this are the larger size of the shipments, the larger number of smaller packages, and often the unpacking and setting up of displays inside the store.

The at-vehicle times were not always easy to estimate. The high average value for clothing stores is again caused by the UPS truck, because the at-vehicle times were not individually recorded, but were computed by subtracting the delivery times and delays from the dwelling times and then dividing the result by the number of multiple deliveries per stop. The at-vehicle time for single deliveries could not always be recorded.

Four subsets of the movement data were used in the regression analysis. Subset A, 378 observations, included all of the data for single and multiple deliveries and single and multiple pickups and deliveries. Subset B, 167 observations, included the data for single deliveries only. Subset C further restricted the single-delivery data to only those deliveries in which the means of transport was by one-man carry and included 87 observations. Subset D, 61 observations, restricted the single-delivery data to deliveries in which the means of transport was by dolly or hand truck.

The dependent variable selected for the most analysis was delivery time. Preliminary regression runs eliminated most of the potential independent variables from consideration. The variables that remained—number of packages, total weight, number of persons per truck, and means of transport—were used as explanatory variables in most of the regression analysis. The table below shows the coefficients of correlation between these variables and delivery time.

Figure 2. Daily vehicle stops and deliveries on Forbes and Murray avenues.

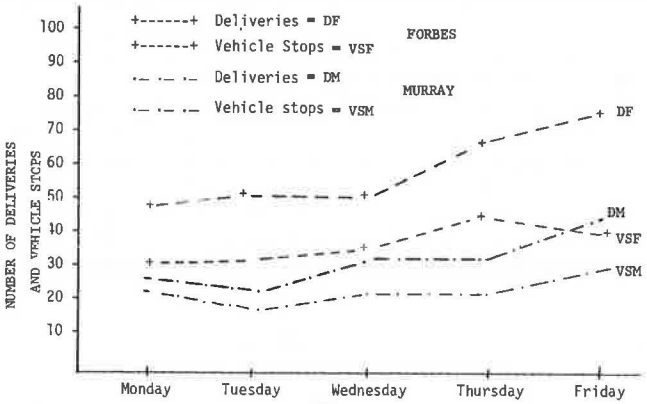
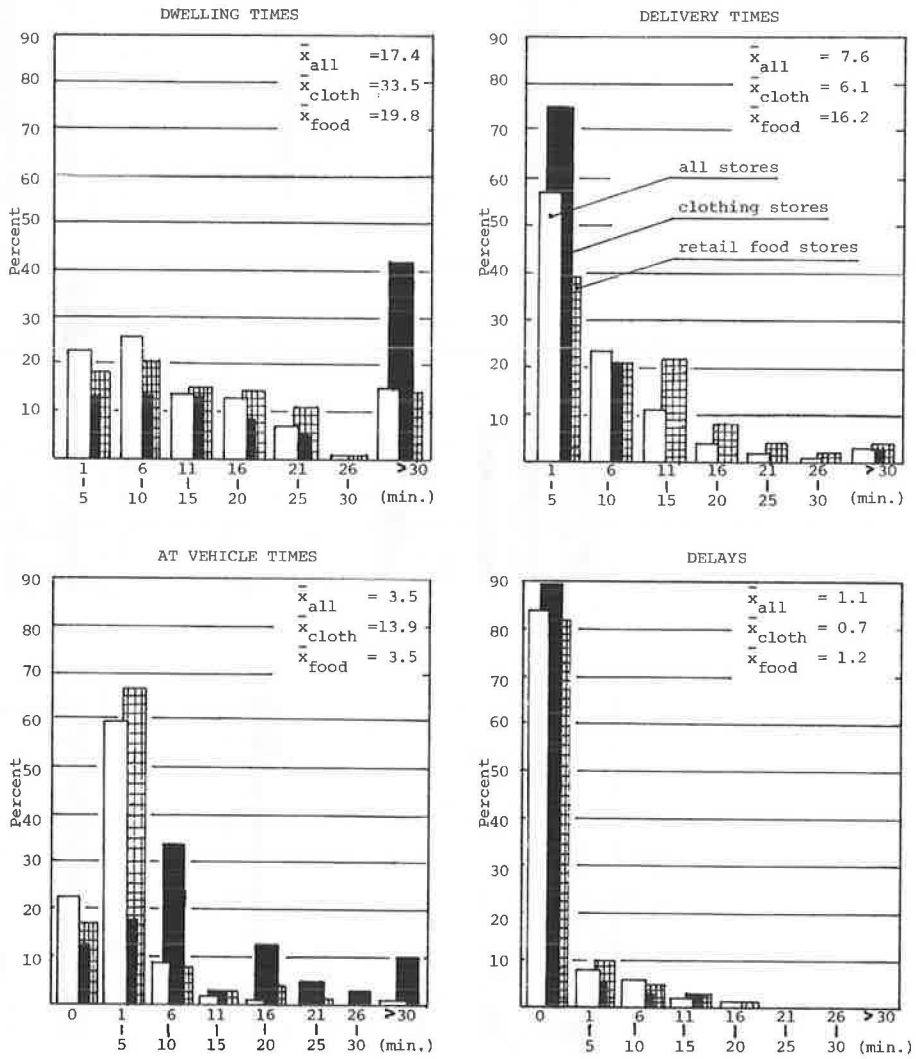


Figure 3. Comparison of delivery characteristics.



Dependent Variable	Delivery Time (T) (min)
Number of packages (P)	0.7215
Total weight (W)	0.7699
Number of persons in truck (N)	0.1413
Means of transport (MT)	0.2648

The PINY work obtained the best results by using delivery time as the dependent variable and number of packages and total weight as the independent variables. The basic equation was

$$T = 1.9 + 0.11P + 0.008W \quad (r^2 = 0.62) \tag{5}$$

where

T = delivery time,
P = number of packages, and
W = total weight.

The best results in testing Equation 5 were obtained by using the data subset that represented single-delivery data only. The equation was

$$T = 4.453 + 0.177P + 0.007W \quad (r^2 = 0.68) \tag{6}$$

The use of the other three data subsets in testing this equation caused little change in the constant term, some changes in the coefficients of the explanatory variables, and significantly lower r^2 values.

Better results were obtained with our data by dropping the constant term from the equation. The equation developed by using the data for single deliveries only was

$$T = 0.28P + 0.008W \quad (r^2 = 0.76) \tag{7}$$

Further improvement in the explanatory powers of the equation was obtained by including the variable for the number of persons per truck. Equations 8, 9, and 10 were developed by using the data for single deliveries only, one-man carry, and dolly or hand truck respectively.

$$T = 0.196P + 0.007W + 3.601N \quad (r^2 = 0.84) \tag{8}$$

$$T = 0.041P + 0.014W + 3.856N \quad (r^2 = 0.80) \tag{9}$$

$$T = 0.302P + 0.001W + 4.578N \quad (r^2 = 0.84) \tag{10}$$

where N = number of persons per truck.

Quantitatively, these results are in substantial agreement with those of the PINY research. The differences in the equations, which may be considered site specific, predict longer delivery times than do those in the PINY equation in both the constant and nonconstant forms. Clearly, there is a need for quantitative analysis of additional study sites having different characteristics to provide a better site basis for comparison.

QUALITATIVE FINDINGS

A number of behavioral characteristics were observed in the study area that could not be adequately quantified. These findings were a composite of the observers' intuitive notions, information supplied by vehicle operators, and opinions expressed by several of the merchants.

The issue of parking legality was of interest because both Forbes and Murray avenues are extensively metered throughout the study area. Not once during the 10 d of observation was a delivery-vehicle operator ever observed inserting coins in a meter. Illegal parking zones in front of fire hydrants, bus stops, driveways, and near intersections were extensively used by delivery vehicles with no evidence of reprimands from policemen. Because the periods of occupancy of these zones were generally quite brief, very little or no interference with their intended purposes was observed. This seems to suggest that many illegal parking zones could function as temporary loading zones with a minimum of interference to normal community operations.

Vehicle operators almost always turn off their engines while making deliveries. Exceptions were noted during cold weather when some operators kept their engines running to provide heat for the cabs of the vehicles. In addition, some refrigerated vehicles have engines left running to keep the perishable payload cooled, and some rubbish vehicles have engines left running to power the hydraulic compactors.

Delays experienced by vehicle operators were recorded in the movement survey, but causal factors were not formally recorded. A general consensus of operators attributes the longest delays to searching for establishment owners or the persons responsible for unlocking delivery-service doors. In one particular instance, a vehicle operator attempted to deliver to a restaurant three different times before successfully gaining access to the basement storage area, because the manager was late arriving at the establishment. Delays were also observed when goods were being picked up. Quite often, packages were not prepared for shipment until the vehicle arrived. Delays were observed from time to time in connection with signing the bill of lading and because of conversations carried on between operators and establishment owners or employees.

There was less correlation between vehicle capacity and shipment size than was expected. Several large straight trucks with payloads of less than five pieces made deliveries during the observation period, but small vans and station wagons with all available space occupied by their shipments were also observed. There was a great deal of variation in packing efficiency among vehicles. The UPS vehicles have shelves catalogued by the names of the establishments along the vehicle route. This system eliminated much of the en-route sorting required of vehicle operators. In contrast, U.S. postal-vehicle operators generally spend a great deal of time along the route sorting packages.

Most vehicle operators were quite concerned with operating efficiency. However, there did appear to be a relation between prevailing weather conditions and operating efficiency. No hard data were collected to support this contention, but observations were made through a wide range of conditions, including 15°F (-9.5°C) with snow showers and sunny days with mild temperatures. There was clearly a reduction in operating efficiency on those days when the weather was inclement.

One example of the general concern for operating efficiency was found in an operator's route plan that served establishments on the east side of a street, went on to the next community, and then served establishments on the west side of the street during the return trip. In cases of pickup and delivery, very few steps were wasted as operators used return trips to the vehicle to transport packages that were being picked up. Some operators expressed a fear that members of the observation team might be time-study personnel representing their employers. However, we believe that what we observed was an accurate portrayal of normal daily operations.

The experiences with the survey completion, data computerization, and data analysis of the business and movement surveys all led to the development of certain conclusions about desirable format and content improvements.

Deliveries that involved one man with a dolly demonstrated the importance of package volume on delivery time. The dolly made it possible for one man to transport a full load of even the heaviest goods, yet required two or more trips for relatively small numbers of packages of large size. Because the number and weight of the packages was less critical in these instances than their number and volume, an estimate of the volume of packages delivered should be included in the movement survey.

It would also be valuable to include a question about the number of store employees involved in the delivery process. The relevance of this was particularly evident in loading-dock deliveries, where packages were typically transferred by a bucket brigade consisting of the driver and one or two store employees. This was one of the fastest delivery systems observed.

At the conclusion of movement surveys in a location, a check should be made with the stores to establish whether the week of observation was a normal one for deliveries. This permits eliminating significantly atypical observations.

SUMMARY AND CONCLUSIONS

The survey format used had the advantage of collecting both empirical and interview data, which allows cross-checking of the results for consistency. The data-collection process was designed specifically to acquire as much data as possible with a very small staff. The movement data were collected in two concentrated areas chosen to provide information about a wide variety of retail establishments, with specific emphasis on food and clothing stores. The observation periods were chosen so that daily patterns would be observed. The hours of observation were chosen to coincide with high levels of delivery activity. The collection periods were chosen to allow comparisons with the results of the business survey.

The distribution analysis indicated similar daily patterns of deliveries. The peaks generally occurred on Friday, regardless of type of establishment. The average Friday delivery rate was about 30 percent higher than the delivery rate on other days. This peak was somewhat higher than that found in the PINY study. Hourly patterns of various retail types were not markedly different, although food stores generally received goods earlier than did other stores.

Analysis of the business-survey data indicated that delivery frequency can be generally correlated to employment, floor space, and product diversity. While the PINY analysis was proven to be too simplistic in this respect, this data base must also be considered too small to permit extensive generalization.

The movement survey was used to find indicators of delivery times. The variables that appeared to have the most correlation were the number and weight of packages. This is in agreement with the PINY findings although the coefficients of the equation developed for the Pittsburgh data were generally higher than those for the New York data. This appears to be an indication of site-specific differences. The volume of a shipment is also fundamental to the delivery time required.

Analysis of the present data base is not complete. Future work will include analysis of other data disaggregations to further determine the characteristics that are most critical in defining the delivery process. Cross-checking the results of the two surveys will aid in identifying consistent biases or errors in interview responses. The effects of the delivery process on traffic congestion are largely unresolved.

The present study leaves as many questions as answers, but it adds needed insight to the urban goods-movement problem. The specific equations found in the analysis are of limited applicability, but the importance of general relationships (and nonrelationships) cannot be overstated. In particular, the points of correspondence and contradiction vis-a-vis the PINY results indicate the types of generalizations and models that may be valid under more extensive testing. The problem of deriving general conclusions from site-specific data is an acute one in urban goods-movement research because there are so many variables distinguishing commercial districts from each other. To date, no clear evidence exists to distinguish the variables that are descriptive from those that are irrelevent. It is hoped that the present study has helped to narrow the focus toward some of the more important relationships.

There is a need for a coordinated series of studies to compile data that are significant to goods deliveries. These data should be collected on a common basis from a wide variety of sites to define valid general relationships and important site-specific variables. Ultimately, a better understanding of these topies can provide tools for planners to use to anticipate the nature of goods movements that any commercial area can be expected to generate.

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**The authors were students at Carnegie-Mellon University when this analysis was completed.*