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PRODUCTIVITY GAINS

FROM DIVERSIFYING THE SANITATION TRUCK FLEET

IN NEW YORK CITY

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I. DESCRIPTIVE SUMMARY

One truck with the same size crew is currently being used for refuse collection in most areas of the City despite wide variations in the operating environments encountered in different parts of the five boroughs. The Fund for the City of New York, in cooperation with the New York Department of Sanitation, the Sanitation Officers Union and the Uniformed Sanitationmen's Association, designed and conducted a test of alternative model refuse collection vehicles to assess the feasibility and potential benefits of diversifying the collection truck fleet. The test was carried out under grants from the federal Environmental Protection Agency, Solid Waste Management Division, and from the Fund for the City of New York.

STUDY DESIGN

The study was based on the hypothesis that collection costs could be decreased, and collection performance increased, through the use of different equipment for different collection environments. Accordingly, the study was to:

- Identify the collection demand characteristics of different areas that could affect equipment and crew performance, e.g.
  - number, type, and weight of refuse receptacles per stop
  - distance between stops
  - tons of refuse per route
  - pedestrian and vehicular flow
  - parking density
  - round-trip truck disposal time
- Identify specific components of collection vehicles that could affect collection performance in different areas, e.g.
  - hopper dimensions (location, payload capacity and compactor efficiency)
  - cab construction and location
  - vehicle weight, dimensions and turning radius
  - self-dumping or removable body
  - repair and maintenance costs and gasoline efficiency

- Develop cost-per-ton and output performance ratings for each type of vehicle tested in each area, and determine optimum crew size.

Three systems, using four types of equipment, were tested, including the vehicle which now makes up the majority of New York City's refuse collection fleet:

- System I -- side loading, 8 cubic yard truck with a detachable container, 2.4 ton payload capacity and a two-sided driving and working cab. One or two men needed to operate.

- Load-A-Matic -- not in itself a system, the LAM is used in conjunction with System I. It hoists System I's container into its own 34 cubic yard body. It has a rated payload capacity of 8 tons and is operated by one man.

- System II -- similar to System I except it has a 12 cubic yard self-dumping body; its rated payload capacity is 3.6 to 4.0 tons; it can be operated by one or two men.

- System III -- the rear-loading 20 cubic yard truck which is now used throughout most of New York (either the Heil Mark IV 25H which was tested or earlier versions of this model). It is self-dumping, has a standard left-hand sided cab, and its rated payload capacity is 7.74 tons. Three men are presently used to operate the vehicle.

The collection systems were tested in two very different collection work environments generally representative of substantial parts of the City: Manhattan East/District 6, which is a high-rise residential and commercial area with heavy pedestrian and vehicular flow and high parking density; and Queens North/District 63, which is a single-family residential area with little or no pedestrian and vehicular flow and little on-street parking.

The following types of data were collected for each system and collection environment:

- Crew refuse collection process data, e.g.
  - crew loading time per stop
  - pounds of refuse loaded per crewman/minute
  - number of stops loaded by one, two or three men

- Equipment refuse collection process data, e.g.
    - hopper loading time by type of refuse receptacle
    - on-route rate of vehicle movement
    - time required to get in and out of the cab
    - actual payload capacity of vehicles
- Workload environmental data, e.g.
    - number, type and weight of refuse receptacles per stop
    - pedestrian and vehicular flow and density
    - refuse disposal site trip time
    - historical route workload data
- Truck-shift time utilization data, e.g.
    - time expended on work preparation and relief activities
    - daily on-route time
    - refuelling process time
- Output and cost data, e.g.
    - tons per truck-shift
    - equipment capital, operating and maintenance costs
    - sanitationman and supervision man/day costs
- Refuse disposal and refuelling methods

These data and structured field observations were carried out by Section Foremen and Fund personnel assigned to each of the collection systems for each day of the test. (The manufacturer of Systems I and II independently monitored the field experiment on selected days throughout the test.) The data collection tasks performed involved counting and stop-watch timing of refuse collection activities with results posted to Fund designed collection instruments.

STUDY FINDINGS

This study's primary purpose was the identification of differently designed truck components and their possible contribution to productivity in different collection areas. The issues of equipment manning levels, effectiveness of field supervision, utilization of truck-shift work time, decentralization of operating authority and disposal and refuelling procedures were also explored. The results of the study findings are detailed in the body of the report.

The findings bear out the hypothesis that equipment appropriate to particular collection environments can contribute to optimizing the safety, ease, time and cost of the collection effort, and that equipment and manning level diversity in the collection function provides an opportunity to improve productivity and secure savings which can be used to reduce the Agency's budget or improve services.

The following vehicle components were identified as being of major potential benefit:

- A side-loading, midship positioned hopper on vehicles deployed in Queens North and similar areas where there are few curb or street obstacles and a substantial portion of the refuse is contained in light weight one-way refuse receptacles. Other areas of deployment could be Queens West, Queens South, and Richmond.

- A rear-loading hopper on vehicles in Manhattan East and similar areas where access to a side-loading hopper is restricted and a substantial portion of the one-way receptacles are extremely heavy due to compacted refuse. Manhattan West is an additional possible area.

- A step-in/step-out cab from which the vehicle can be controlled from the left or right side for safe, quick and easy getting in and out, for use on all vehicles in all areas of New York City.

- A 10-ton payload capacity vehicle to be deployed in long-haul disposal areas such as Queens North to reduce disposal trip frequency and provide adequate vehicle capacity to hold the entire amount of refuse generated by a route.

In addition, the test results indicate there are significant benefits in the deployment of two-man crews with appropriate equipment in areas similar to Queens North. Refuse collection costs in the three Queens zones and Staten Island, representing 20 of the City's 58 districts, could be reduced by $16.1 million through the manning of the appropriate vehicles with two-man crews. However, the study also suggests that none of the potential benefits of improving the fit between collection demand characteristics on one hand and resources (vehicle design and manning levels) on the other hand will be realized without tightened controls by field management over the utilization of crew time. Under-utilization of truck-shift work time reduced the paid work period by 14.9% to 18.3% in the two test areas. Retrieval of this time in the 30 districts which are roughly similar to Districts 6 and 63 would have reduced collection costs by $13.833 million based on fiscal year 1976 costs.

Diversification of the City's virtually homogeneous collection fleet is one element in a process which could produce a potential annual saving of $25 to $30 million in the Sanitation Department's operations. Establishing the appropriate mix of vehicle, manning level, collection route, and work standards for each area of the City according to its collection demand characteristics should be a Sanitation Department priority, and would provide a means for making these potential savings real.

If the City decides to move ahead with a fleet diversification program it should be possible to secure federal funding and some foundation support to assist its efforts. The focus of the program should be on operating a series of prototypes so that the Department can determine the benefits of a wide range of vehicles and different manning levels functioning under actual field conditions for significant periods of time. The major analytic and experimental components of a fleet diversification program are described below:

- The classification of the 254 sanitation sections according to their collection demand characteristics.

- Selection of a series of vehicles whose design components match the major collection demand characteristics of each section grouping.

- Acquisition of the selected vehicles through a combination of vendor consignment, lease, lease with an option to buy, and direct purchase.

- Establishing a series of operating prototypes in which new and existing vehicles with appropriate manning levels could be evaluated under normal field conditions for each type of area. Collection routes and work standards would be adjusted for each prototype depending upon the collection demand characteristics of the area, vehicle, and manning level.

- Evaluation of the field results of the prototypes and maintenance data collected for the Department's new system will provide the information required to select the most appropriate vehicles for each group of sanitation sections.

II. VEHICLE DESCRIPTIONS

Four different types of vehicles were tested in Queens and Manhattan:

SYSTEM I

A side-loading refuse collection vehicle with an 8-cubic yard detachable container weighing (dry) 12,670 pounds, supported by a 126-inch wheelbase. Overall length is 276 inches. The vehicle uses regular gasoline and can be driven from either the left or right side of a step-in/step-out cab behind which is positioned a side loading refuse hopper. Compaction is performed by a horizontally moving bulkhead that can be activated by controls located in the cab, and on the left and right side of the hopper.

The hopper loading height is 43 inches above the ground. Its dimensions are 36"(L) x 47"(W) x 28"(D). There is a full length riding step on both sides of the hopper. Its rated payload capacity is 2.4 tons.

Equipment manning level: 2 men. Tested: Queens, Manhattan. Manufacturer: LoDal.

Load-A-Matic (E-Z Pak type vehicle)

The Load-A-Matic is not in itself a system. It supports System I by hoisting I's container, dumping it into its own body and replacing the container in the transfer site. The LAM is an 18,160 pound front-end loader with a 34 cubic yard body and a payload of approximately 8 tons. It is equipped with a triangular shaped coupling part capable of hoisting up to a 10,000 pound payload at a dump angle of 60 degrees. Overhead hoisting clearance is 175 inches and outside length, with volume extender bustle, is 272.75 inches.

Equipment manning level: 1 man. Tested: Queens, Manhattan. Manufacturer: LoDal.

SYSTEM II

Same as System I, except it has a self-dumping 12 cubic yard body with a weight (dry) of 13,400 pounds and an overall length of 293 inches. Its rated payload capacity is 3.6 to 4.0 tons.

Equipment manning level: 2 men. Tested: Manhattan only, since Queens is a long-haul disposal area.* Manufacturer: LoDal.

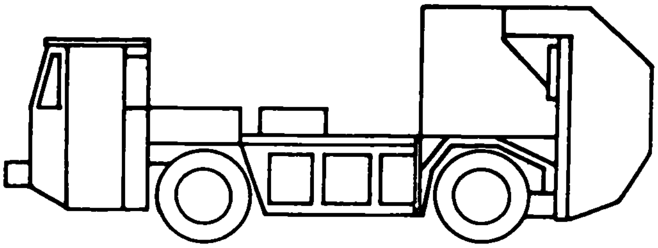
SYSTEM III

This Heil (Mark IV 25H) is a rear-loading vehicle with a 20 cubic yard body and a tare weight of 24,600 pounds, on a 202 inch wheelbase. Its overall length is 336 inches. The truck uses regular gasoline and is driven from a standard cab. Compaction is performed by a blade activated by controls located on the left and right side of the hopper. These controls are equipped with a "deadman switch" which requires continuous application of pressure to compact. This model constitutes approximately 25% of N.Y.C.'s Department of Sanitation collection fleet. Earlier versions of the Mark IV make up most of the remaining 75%. Rated payload 7.74 tons.

Equipment manning level: 3 men. Tested: Queens; Manhattan. Manufacturer: Heil.

*Here defined as areas whose disposal site is fairly far, such as Queens North (12 mile, 82.6 minute roundtrip), as opposed to Manhattan East (1.5 mile, 31.7 minute roundtrip).

SYSTEM I & II



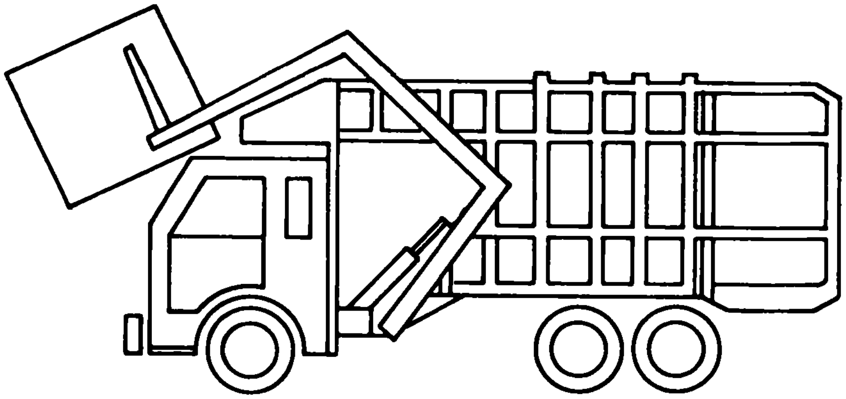
System I

Transferable Container

System II

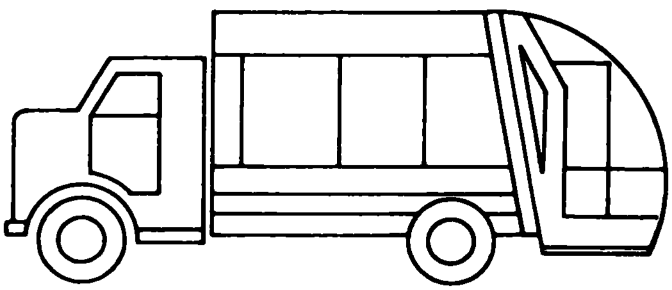
Fixed Container

TRANSFER VEHICLE



Operates in conjunction with System I

SYSTEM III



Current System

III. PROJECT TEST SPECIFICATIONS

TEST SITES

Under the joint supervision of the Department of Sanitation, the Sanitation Officers Association, the Uniformed Sanitationmen's Association and the Fund for the City of New York, two areas were selected as representative of the range of collection operating conditions in New York City. The testing began on January 11, 1977 and continued for six weeks, until February 18, 1977. The test was divided into two three-week periods.

District 63/Queens North:

This is a predominantly residential area with a preponderance of single-family homes. The streets are wide; there is little vehicular flow; on-street automobile parking is scarce as most cars are stored in garages or driveways. Pedestrian traffic is dispersed.

The area receives collection service twice weekly. The average interval between collection stops is 104 feet; the stops have an average of 2.3 refuse receptacles whose total weight is approximately 30.9 pounds (higher in the Fall and Spring), and 36% of them are one-way receptacles. Each individual receptacle weighs an average of 13 pounds and is loaded into the collection truck with little sidewalk or street obstruction.

District 6/Manhattan East:

This is a mixed-use area of main avenues and side-streets with commercial establishments as well as multiple dwellings of six to more than 25 stories. The high-rise housing units generate highly compacted refuse in plastic or paper bags. Vehicular flow is heavy; there is considerable on-street single and double parking by private and commercial vehicles. Pedestrian traffic is also substantial.

At the time of the test the area was receiving collection service five times a week. Refuse collection stops occur approximately every 168 feet and have an average of 6.6 receptacles per stop, or nearly three times as many as District 63/Queens. The total weight of the receptacles average 166.1 pounds, a figure which remains fairly consistent year-round. The lower limit of the average is 142 pounds, the upper limit 210, or 4.5 to almost 7 times heavier than a Queens North stop. The average percentage of one-way receptacles is 62%, many weighing in excess of 50 pounds. See Table 1, Profile of Test Area, page 9.

TABLE 1

PROFILE OF TEST AREAS

CHARACTERISTICS	QUEENS · 63	MANHATTAN · 6
Use of Area	Residential	Residential, Commercial
Type of Housing	Mostly Single Family homes	Multiple Dwellings, High Rise
Auto Parking/Flow	Light	Heavy
Collection Frequency	2 times weekly	5 times weekly
Collection Stop Density	104 feet between stops	168 feet between stops
Average Refuse Receptacles Per Stop	2.3	6.6
Percent 1-Way Receptacles	36%	62%
Average Weight Per Stop	30.9 lbs.	166.1 lbs.
Disposal Time and Distance	82.6 min./12 miles	31.7 min./1.5 miles

RECRUITMENT, TRAINING AND ASSIGNMENTS OF TEST PERSONNEL

The selection process of vehicle crews and Section Foremen was determined and conducted by their respective unions. Rotation of vehicle and crew assignments was performed every few days, except for the operators of the Load-A-Matic who were not rotated.

Section Foremen were trained by the Fund for the City of New York in the collection of route process data, disposal and refuelling procedure data and output performance data. Specific tasks included counting (e.g. stops, refuse receptacles, miles on route, gallons of gas, etc.); and stop-watch timing (e.g. elapsed time to clear refuse from a collection stop, cab egress time, travel time between stops, lunch-break time, etc.). The results were posted to data collection instruments designed by the Fund. One Section Foreman was assigned to each vehicle for each day of the test period.

The manufacturers of the vehicles provided training for the equipment; operators were instructed in their District garages, followed by a full day of field practice.

IV. DESIGN OF VEHICLE COMPONENTS WHICH IMPACT ON CREW PERFORMANCE

The components of refuse collection trucks assumed to be most relevant to collection productivity are:

1. Hoppers (See Table 2, page 13.)
2. Cab
3. On-Route Movement (encompassing vehicle dimensions, tare weight, riding step and turning radius; see Table 4, page 16)
4. Payload Capacity

Although Systems I, II and the Load-A-Matic collected and disposed of refuse at a slightly greater unit cost than System III, the design features of certain components of Systems I, II and the Load-A-Matic offered significant advantages over System III. The results of the tests follow.

HOPPERS

The relevant features of a hopper are its location and dimensions. (See Table 3, page 14.)

- In District 63/Queens North, the mid-ship positioned side-loading hopper of System I offered the vehicle's crew more time and ease of loading with one-way refuse receptacles (non-returnable containers), but not with bulk refuse (stoves, water-heaters, etc.).
  - System I's 4.4 seconds needed to load a one-way receptacle was .9 of a second faster than the 5.3 seconds of System III.
    - Unobstructed access allowed the crew to throw the lightweight (13 lb.) one-way receptacles into System I's hopper.
    - Enclosing walls of System III's hopper required crew to walk from curb to hopper.
  - System I's 22 seconds to load a bulk item was 11.1 seconds slower than the 10.9 seconds of System III.
    - System I's hopper was either too shallow or its entrance too narrow - 36 inches versus 80 inches on System III - to accept a bulk item in its entirety. Repeated compaction cycles were required before a large object could be accommodated.

- The horizontally moving bulkhead of the mid-ship positioned hopper impacted bulk items at their midpoint, causing the phenomenon of "bridging".

- Greater crew set-up time was needed to hoist a bulk item to a height of 43 inches and place it in System I's hopper from 15 inches away from the hopper.

• In District 6/Manhattan East, the collection operating conditions nullified the design advantages of System I's mid-ship positioned hopper and resulted in longer loading times, on average, for all receptacle types.

  •• System III's 6.6 seconds to load a one-way receptacle was 2.1 seconds faster than the 8.7 seconds of Systems I and II.

    - District 63 had one-way refuse receptacles that were light enough to be thrown into the midship hopper with its unobstructed perpendicular access; District 6 had one-way refuse receptacles weighing two to four times as much, preventing such receptacles from being tossed into the hopper.

    - The rear-positioned hopper of System III did not encounter obstacles in the area behind the truck so that unobstructed space was available to swing items into the hopper.

    - Swing space at the side of the collection vehicle was severely constrained in District 6 due to high-density street parking which often put the mid-ship hopper flush against parked cars.

  •• Systems I and II achieved an average loading time per bulk item of 40.6 seconds, 29.9 seconds slower than the 10.7 seconds of System III.

    - Lack of swing space, smaller hopper dimensions, the bridging phenomenon and greater crew set-up time contributed to the slower bulk loading time of Systems I and II.

TABLE 2

DESIGN PROFILES OF SYSTEM I/II AND SYSTEM III LOADING HOPPERS[1]

HOPPER DESIGN ELEMENTS	SYSTEM I/II[2]	SYSTEM III[3]
Position	Midship Behind Vehicle Cab	Rear of Vehicle
Dimensions	1 Cubic Yard[4]	1 Cubic Yard[5]
•Length	36 inches	49 inches
•Width	47 inches	80 inches
•Depth	28 inches	18 inches
Hopper Access	Loading Entrance 36 inches Unobstructed Perpendicular Access to Hopper Loading Entrance	Loading Entrance 80 inches Side Panels of Hopper Sack Prevent Perpendicular Access to Hopper
Loading Height	43 inches	38 inches

[1]System I/II refer to the LoDal 8 cubic yard and 12 cubic yard vehicles tested in Queens and Manhattan. Both have identical loading hopper specifications. System III refers to the Heil Mark IV 25H collection vehicle.

[2,3]Design profile data on hopper for System I/II obtained from manufacturer's specifications and System III from Bureau of Motor Equipment, Department of Sanitation.

[4,5]1 cubic yard measures volume of water hopper can contain at rest.

TABLE 3

EQUIPMENT FEATURE DESIGNED TO IMPROVE COLLECTION PRODUCTIVITY: LOADING HOPPER

EQUIPMENT FEATURE	QUEENS DISTRICT #63[1] AVERAGE LOADING TIME (seconds)			MANHATTAN DISTRICT #6[2] AVERAGE LOADING TIME (seconds)		
	1-WAY REFUSE RECEPTACLE	2-WAY REFUSE RECEPTACLE	BULK REFUSE	1-WAY REFUSE RECEPTACLE	2-WAY REFUSE RECEPTACLE	BULK REFUSE
MIDSHIP POSITIONED HOPPER	4.4 secs.	9.1 secs.	22.0 secs.	8.7 secs.	11.0 secs.	40.6 secs.
REAR POSITIONED HOPPER	5.3 secs.	9.1 secs.	10.9 secs.	6.6 secs.	11.0 secs.	10.7 secs.

[1] 21% sample for midship positioned hopper; 23% sample for rear positioned hopper.

[2] 38% sample for midship positioned hopper; 35% sample for rear positioned hopper.

CABS

Cab design can affect the time and ease of the driver's getting in and out, can facilitate or impede his participation in the loading function, and can affect worker safety.

- In District 6/Manhattan East the number of refuse items per stop -- an average of 6.6 receptacles together weighing 142 to 210 pounds -- generated high cab egress frequency for the second and third man of the 2 and 3 men crews of Systems I, II and III at 82.5% and 41% of all stops, respectively.

  - The elapsed time for the driver to leave the standard cab of System III and arrive at the refuse was 6.9 seconds.

  - The elapsed time for the driver to leave the step-in/step-out cab of Systems I and II and arrive at the refuse was 3.7 seconds, i.e. 3.2 seconds <u>faster</u> than the same trip from System III.

    - A smaller effort is required to leave the step-in/step-out cab than to leave the standard cab, thus preserving the collector's effort for the loading task.

    - The man leaving the step-in/step-out cab avoids stepping out into the often heavy passing traffic streams of District 6/ Manhattan East. The driver can leave from either side of a two-sided working cab.

ON-ROUTE MOVEMENT

While not actually a design component, the rate of on-route movement is determined by a number of components of collection trucks. Specifically, the vehicle's dimensions, engine, tare weight, and presence of a riding step all impact on its ability to progress from stop-to-stop. (See Table 4, page 16.)

- Specification statistics regarding vehicle wheelbase, overall length and width, turning radius and tare weight show that System I and System II are smaller and lighter than System III.

- Systems I and II are equipped with a riding step designed to transport the crewmen between stops at the vehicle's pace, not at the walking pace of the crew.

- System II in District 6/Manhattan East was equipped with a front-wheel steering mechanism capable of tracking on a smaller radius than System I.

TABLE 4

—VEHICLE SPECIFICATIONS—
ON-ROUTE MOVEMENT

	2-MAN LO DAL 8 CUBIC YARDER	2-MAN LO DAL 12 CUBIC YARDER	3-MAN HEIL 1976 MARK IV
Wheelbase (inches)	126"	126"	202"
Turning Radius (over bumper)	36'	36'	39'
Overall Length (inches)	276"	293"	336"
Overall Width (inches)	94"	94"	102"
Tare Weight (pounds)	12,670 lbs.	13,400 lbs.	24,600 lbs.
Engine	V8 318 cu. inches	V8 318 cu. inches	V8 478 cu. inches
Torque	245 lb. - FT at 1800 RPM	245 lb. - FT at 1800 RPM	not available

TABLE 5

ON-ROUTE MOVEMENT OF VEHICLES
QUEENS · 63

VEHICLE	RATE OF ON-ROUTE MOVEMENT (feet per second)[1]
System I	3.60 feet per second
System III	4.91 feet per second
Performance Difference	System III 36.4% faster rate

[1]Direct time measurement conducted on 1/17 and 1/25 of test period. On 1/21, 24, 26 and 27 direct measurement of time spent loading while on the route. Subtracted this from total time spent on the route yielded time spent travelling between stops on these days.

TABLE 6

ON-ROUTE MOVEMENT OF VEHICLES
MANHATTAN · 6

VEHICLE	RATE OF ON-ROUTE MOVEMENT (feet per second)[1]
System I	4.54 feet per second
System II	5.02 feet per second
System III	5.78 feet per second
Performance Difference	System III 15% to 27% faster rate

[1]Direct time measurement conducted on 2/3, 7, 9 and 10 of test period.

A comparative analysis was conducted in both test areas to determine if the smaller, lighter vehicles of Systems I and II obtained a faster on-route travel rate than System III. The results show that:

- In District 63/Queens North, System I had slower travel rates than System III. (see Table 5, page 17)
  - System I vehicles achieved a travel rate of 3.60 route feet per second while travelling from one stop to the next.
  - System III achieved a travel rate value of 4.91 feet, or 36.4% faster average on-route speed.
- In District 6/Manhattan East, according to the speed measure of feet-per-second, System III negotiated its route at the fastest rate. (see Table 6, page 17)
  - Systems I and II achieved a value of 4.54 and 5.02 feet per second, respectively.
  - System III achieved a value of 5.78 feet per second.
- Contrary to expected rates of route travel, all Systems obtained a faster rate under the more highly congested and obstructed route conditions of Manhattan East than Queens North.

PAYLOAD CAPACITY

This is an important aspect of vehicle design as it affects fleet replacement costs, disposal frequency, the volume of maintenance workload and full utilization of crew-time. Determination of the payload capacity value is a function of the weight of the refuse generated in an area, service frequency, crew output performance standards, cost of disposal frequency, and fleet acquisition plans. These factors make it a more complex design component to evaluate than hoppers, cabs, or truck dimensions since it must be analyzed in conjunction with all of these issues.

The payload capacity of a refuse collection vehicle should be equivalent to or somewhat larger than the workload generated by a collection route, subject to the limitations on vehicle size imposed by an area's street grid. Idle crew time ought not to result from payload shortfall; marginally excessive vehicle payload is less costly than under-utilized crew time.

- A fleet composed of vehicles with a payload too small to service one entire route will result in excessive capital expenditures to acquire a sufficient number of vehicles to service a District's daily routes.

- Since a refuse collection vehicle is a mobile container requiring its contents to be emptied when full, the larger the container, the more refuse it can hold. Additional capacity can reduce disposal trip frequency and cost.

- A smaller fléet (of larger payload trucks) can reduce the number of maintenance jobs: two vehicles have twice as many systems, assemblies and parts that can potentially malfunction.

An imbalance between vehicle payload and route workload, which can result from either an incorrectly specified payload rating and/or under-utilization of payload capacity, can cause unnecessarily large purchases of trucks, excessive and costly disposal frequency and a higher than necessary maintenance workload.

In the Command Zones of Queens North, Queens South, Queens West and Richmond such an imbalance exists. As a result, many routes are served by two collection trucks instead of one, a procedure which is used to maximize crew collection time in long-haul disposal areas. In District 63 a second, empty collection truck is conveyed to the route so that the crew can continue collection, avoiding the 82.6 minute round-trip to the marine transfer station. The refuse contained in these second trucks is disposed of during the 4-12 or 12-8 shifts.

An analysis of route workload levels and truck loads for Fiscal Year 1975-76 revealed the following:

- In Command Zones Queens North, South, West and Richmond, the mean payload per truck load (not truck shift) was 4.51 tons in 1975-76.

- In District 63/Queens North the average during the field test was 3.71 tons per truck load.

  - These represent 3.23 to 4.03 tons, or 42% to 52% under-utilization of the Heil Mark IV's rated payload of 7.74 tons.

- In Command Zones Queens North, South, West and Richmond the mean workload per route ranged from 8.08 tons to 10.42 tons.

  - This route workload range exceeds the rated payload capacity of the Heil Mark IV by 14% to 35%.

- To service routes that generate a daily average workload of 8.08 to 10.42 tons would require the frequent deployment of 1.84 to 2.07 trucks per daily route. (As trucks are indivisible 2 trucks would frequently be deployed.)

This analysis strongly suggests that long-haul disposal areas require a vehicle with a payload value equivalent to the total daily route workload. Even if fully utilized, which it is not, the Heil Mark IV is inadequate to hold the refuse generated by percent routes in Queens North, South, West or Richmond.

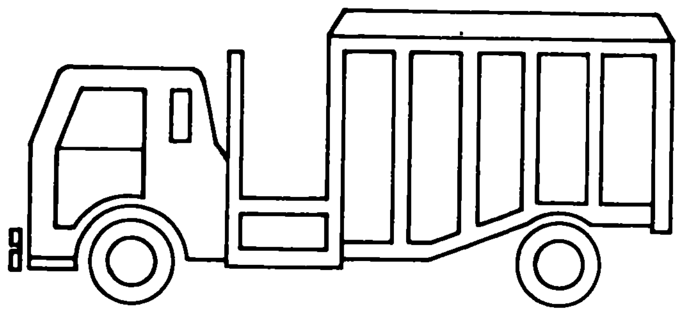
To determine the correct vehicle payload value for these areas an analysis of the weekly average route workloads for the Fiscal Year 1975-76 was performed (52 weekly averages for 20 districts):

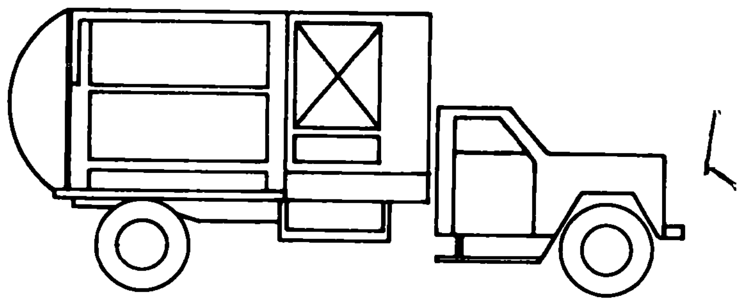
- The probability that an average route in any given week in Queens North, South, West or Richmond would generate a workload of less than 7.74 tons is .044.
  - One Heil Mark IV, with a payload rating of 7.74 tons, would be able to service the total workload of the average route only 4.4 percent of the time.
  - To complete the collection of refuse from an average route in any given week would require the relaying of a second truck 95.6 percent of the time.
- The probability that an average route in these same Command Zones would generate a workload of 8.6 to 10.0 tons is .66.
- The probability that an average route in any given week in these same Command Zones would generate a workload greater than 10.0 tons is .144.

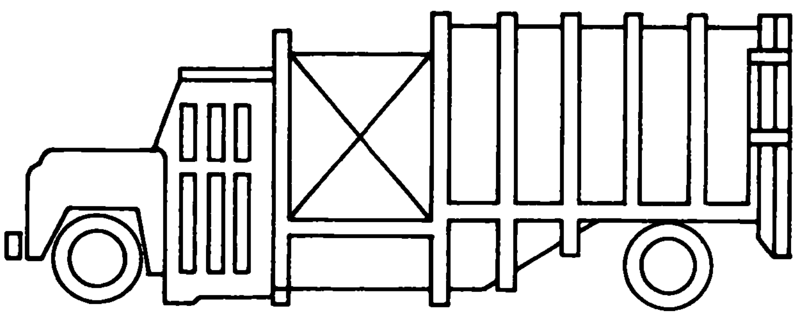
This analysis demonstrates that one Heil Mark IV would be incapable of collecting the total workload of the average weekly route 95.6 percent of the time.

The cost-effective payload value of a refuse collection vehicle to be deployed in the above zones would seem to be approximately 10 tons; 44% of the routes generate workloads in the range of 9.1 to 10 tons per day.

OTHER TYPES OF SIDE LOADING VEHICLES







V. COMPARATIVE COST PERFORMANCE ANALYSIS

There is much disagreement as to how to achieve true cost measurements in refuse collection. The standard most often relied on is cost-per-ton. The measurement used in the study carried out by the Fund for the City of New York similarly uses cost-per-ton, in addition to the calculation of cost per equivalent refuse collection stop. This latter calculation corrected for route imbalances that occurred during the field test by equalizing the primary determinant of workload: the number and type of refuse receptacles at the collection stop.

The one-time developmental costs, the recurring operating and maintenance costs, and the opportunity costs associated with transfer sites for System I are not included in this cost analysis for the following reasons: first, because no cost estimates relevant to New York City residential neighborhoods could be derived; and second, it was difficult to assess the political costs involved in siting mini-dump points in residentially dense New York City.

In addition, the cost analysis of System I proceeded from the assumption that minimization of total and unit cost is partially a function of the number of additional containers needed at a transfer site. (Additional containers are needed to insure the operational independence of the route vehicle--System I--from the Load-A-Matic if disposal delays, such as those which occur at the City's marine transfer stations, are to be avoided.) This cost analysis therefore assumes only one additional container per transfer site, regardless of the number of System I vehicles served by a site. To achieve this minimization of the contribution to total and unit costs would require major operational changes such as staggered dispatching of vehicles and a stretch-out of the work day beyond its current 7 to 3 time period. In addition, the rate of travel and loading of each vehicle would have to be confined to a certain domain, otherwise two or more vehicles would arrive at the transfer site with only one empty container. Noting these exceptions, an analysis of the cost and performance test data revealed the following: (see Table 7, pages 23 & 24)

- In District 63/Queens North, the Heil Mark IV was cost competitive with System I and the Load-A-Matic (see Tables 8 and 9, pages 25 & 26).[1]
  - Total cost to perform collection, disposal and refuelling activities during the test period was $11,045.23 for both System I vehicles:
    - Cost per ton $97.06.
    - Cost per equivalent stop $1.493.[2,3]
  - Total cost to perform collection, disposal and refuelling activities during the test period was $8,146.13 for System III:

- Cost per ton was $95.00 or 2.2% less costly than both System I vehicles and the Load-A-Matic.

- Cost per equivalent stop was $1.497 or .27 hundreths of a percentage point more costly than both System I vehicles and the Load-A-Matic.[2,3]

·· System I and the Load-A-Matic achieved these unit costs by collecting, on average, 4.061 tons from 264.116 equivalent stops per truck-shift.

·· System III (Heil Mark IV) achieved a lower cost per ton by collecting, on average, 6.125 tons per truck-shift.[4]

· In District 6/Manhattan East, the Heil Mark IV was, as in District 63, cost competitive with System I, II and the Load-A-Matic (see Tables 10 and 11, pages 27 & 28).[5]

·· Total cost to perform collection and disposal activities (District 6 refuelling procedure did not consume the equipment and manpower resources as it did in District 63) during the test period was $5,136.32 for System I and the Load-A-Matic:

- Cost per ton $44.51.

- Cost per equivalent stop $3.512.

·· Total cost to perform collection and disposal activities during the test period was $4,885.54 for System II:

- Cost per ton $44.58.

- Cost per equivalent stop $3.686.

·· Total cost to perform collection and disposal activities during the test period was $6,796.49 for System III:

- Cost per ton was $42.08:
  -- 5.5% less costly than System I.
  -- 5.6% less costly than System II.

- Cost per equivalent stop was $3.608:
  -- 2.66% more costly than System I.
  -- 2.73% less costly than System II.

·· System I and II achieved these unit costs by collecting, on average, 8.243 tons and 7.829 tons from 94.876 and 94.681 equivalent stops per truck-shift.

·· System III achieved a lower cost per ton and cost per equivalent stop by collecting, on average, 11.537 tons from 134.556 equivalent stops per truck-shift.

TABLE 7

LABOR AND EQUIPMENT COST VALUES USED
IN THE FIELD TEST COST PERFORMANCE ANALYSIS

LABOR COST VALUES [1]	
• Cost Per Sanitationman Man-Day	$91.55
• Cost Per Supervision Man-Day	$107.97
• Post Coverage Factor Per Man-Day	.50
EQUIPMENT COST VALUES [2]	
• SYSTEM I	
•• Cost of Unit	$31,000.00
•• Depreciation Per Truck-Shift (5 years at 290 operating days per year)	$21.38
•• Vehicle Service and Maintenance Cost Per Truck-Shift	$15.20
•• Fuel Cost Per Gallon (Regular Gas)	$0.3910
•• Container Cost Per Vehicle Per Truck-Shift	$0.19 to $0.38
• SYSTEM II	
•• Cost of Unit	$35,000.00
•• Depreciation Per Truck-Shift (5 years at 290 operating days per year)	$24.14
•• Vehicle Service and Maintenance Cost Per Truck-Shift	$15.20
•• Fuel Cost Per Gallon (Regular Gas)	$0.3910

Table 7 (cont.)

• LOAD-A-MATIC	
•• Cost of Unit	$58,512.00
•• Depreciation Per Truck-Shift (5/7 years at 290 operating days per year)	$28.82 to $40.35
•• Vehicle Service and Maintenance Cost Per Truck-Shift	$30.00
•• Fuel Cost Per Gallon (Diesel Fuel)	$0.4140
• SYSTEM III	
•• Cost of Unit	$29,040.00 to $34,040.00
•• Depreciation Per Truck-Shift (5 years at 290 operating days per year)	$20.03 to $23.48
•• Vehicle Service and Maintenance Cost Per Truck-Shift	$19.40
•• Fuel Cost Per Gallon (Regular Gas)	$0.3910

[1]Provided by Department of Sanitation.

[2]Provided by Bureau of Motor Equipment, Department of Sanitation for System III and LoDal, Inc. for Systems I, II and the Load-A-Matic.

TABLE 8

FIELD TEST COST ANALYSIS · QUEENS NORTH/DISTRICT 63

LABOR COSTS	SYSTEM I	SYSTEM III
• Sanitationman Man-Days (collection, disposal, refuelling and post coverage factor)	91.16 man-days	71.04 man-days
• Sanitationman Costs	$8,345.71	$6,503.72
• Supervision Man-Days (actual ration of 1 section foreman to 3-5 routes per day and post coverage factor)	8.4 to 13.98 man-days	4.2 to 6.99 man-days
• Supervision Costs	$906.95 to $1,509.42	$453.48 to $754.51
TOTAL LABOR COSTS	$9,252.66 to $9,855.13	$6,957.20 to $7,258.43
EQUIPMENT COSTS	**SYSTEM I**	**SYSTEM III**
• Truck-Shifts (collection, disposal, refuelling)	32.77 truck-shifts	19.36 truck-shifts
• Depreciation Costs	$723.39 to $758.67	$387.78 to $454.57
• Container Costs	$5.32 to $8.96	no container
• Service and Maintenance Costs	$543.39	$375.58
• Fuel Costs	$199.777 (regular and Diesel)	$241.560
TOTAL EQUIPMENT COSTS	$1,471.87 to $1,510.797	$1,004.92 to $1,071.71
GRAND TOTAL COST	$10,724.53 to $11,365.93	$7,962.12 to $8,330.14

TABLE 9

FIELD TEST UNIT COST ANALYSES COMPARISONS
QUEENS NORTH/DISTRICT 63

	SYSTEM I	SYSTEM III
GRAND TOTAL COSTS	$11,045.23	$8,146.13
- Total Tons Collected	113.8 tons	85.75 tons
- Cost Per Ton	$97.06	$95.00
- Unit Cost Difference		2.2% less costly
- Total Equivalent Stops	7,397.227	5,441.937
- Cost Per Equivalent Stop	$1.493	$1.497
- Unit Cost Difference		0.27% more costly

TABLE 10

FIELD TEST COST ANALYSIS · MANHATTAN EAST/DISTRICT 6

LABOR COSTS	SYSTEM I	SYSTEM II	SYSTEM III
• Sanitationman Man-Days (collection, disposal, post coverage factor)	44.53 man-days	42.44 man-days	63.93 man-days
• Sanitationman Costs	$4,076.81	$3,884.94	$5,851.20
• Supervision Man-Days (actual field ratio 1 section foreman to 8-9 routes and post coverage factor)	3.27 to 3.68 man-days	3.44 to 3.87 man-days	2.33 to 2.63 man-days
• Supervision Costs	$353.06 to $396.79	$370.98 to $417.84	$251.03 to $283.42
TOTAL LABOR COSTS	$4,429.87 to $4,473.60	$4,255.92 to $4,302.78	$6,102.23 to $6,134.62
EQUIPMENT COSTS	**SYSTEM I**	**SYSTEM II**	**SYSTEM III**
• Truck-Shifts	15.69 truck-shifts	14.29 truck-shifts	14.63 truck-shifts
• Depreciation Costs	$347.94 to $367.39	$344.96	$292.90 to $343:35
• Container Costs	$4.76 to $5.37	no container	no container
• Service and Maintenance Costs	$263.41	$217.21	$283.69
• Fuel Costs	$58.44	$44.02	$76.25
TOTAL EQUIPMENT COSTS	$674.55 to $694.61	$606.19	$652.84 to $703.29
GRAND TOTAL COST	$5,104.42 to $5,168.21	$4,862.11 to $4,908.97	$6,755.07 to $6,837.91

TABLE 11

FIELD TEST UNIT COST ANALYSES COMPARISONS
MANHATTAN EAST/DISTRICT 6

	SYSTEM I	SYSTEM II	SYSTEM III
GRAND TOTAL COSTS	$5,136.32	$4,885.54	$6,796.49
- Total Tons Collected	115.4 tons	109.6 tons	161.5 tons
- Cost Per Ton	$44.51	$44.58	$42.08
- Unit Cost Difference			5.5% less costly than System I
			5.6% less costly than System II
- Total Equivalent Stops	1,462.35	1,325.54	1,883.78
- Cost Per Equivalent Stop	$3.512	$3.686	$3.608
- Unit Cost Difference			2.66% more costly than System I
			2.73% less costly than System II

VI. EQUIPMENT MANNING LEVELS

The study conducted by the Fund for the City of New York to evaluate alternative refuse collection vehicles also provided an opportunity to analyze the efficiency of different size operating crews. Our findings with regard to manning levels closely parallel the findings of others:* in general, smaller crews are more productive than larger ones within certain collection environments.

Systems I, II were manned by four 2-man crews and III by two 3-man crews. The study sought to determine if the rate at which each crewman loaded refuse per stop and the portion of available crew manpower used to perform this activity differed according to crew size.

- The average refuse collection stop in District 63/Queens North has the following loading performance related characteristics:
  - 2.3 refuse receptacles weighing 30.9 pounds.**
    - 36% being one-way receptacles weighing, on average 13 pounds.
    - 61% being two-way receptacles.
    - 3% being bulk refuse.
  - Unobstructed curbside or gutter with refuse placed at a similar spot in front of each home, providing continuity of refuse pick-up and close proximity of truck to refuse.
- In District 63/Queens North, the performance difference, as measured by mean crew loading time per stop, was zero seconds. (See Table 12, page 30.)[6]
  - 2-man crews loaded a refuse stop, on average, in 19 seconds.
  - 3-man crew loaded a refuse stop, on average, in 19 seconds.

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*E.g., The Institute for Solid Wastes of the American Public Works Association in its 4th Ed. of Solid Waste Collection Practice found that while collection trucks are getting larger, crew sizes are getting smaller; and a recent comprehensive evaluation, funded by the United States Environmental Protection Agency, of eleven municipal solid waste collection systems noted that "...the one-man crew is (statistically) more productive than his counterpart in multi-man crews." (Residential Collection Systems, Vol. I, Report Summary 1974, ACT Systems, Inc., pp. 39-47.)

**2.25 refuse receptacles and 29.5 pounds per stop for System I and 2.47 refuse receptacles and 33.12 pounds per stop for System III during field test.

TABLE 12

MEAN CREW LOADING TIME PER STOP[2]

QUEENS DISTRICT #63		MANHATTAN DISTRICT #6	
System I 2-Man Crew	19 seconds	System I/II[1] 2-Man Crew	72 seconds
System III 3-Man Crew	19 seconds	System III 3-Man Crew	69 seconds
PERFORMANCE[3] DIFFERENCE	0 seconds	PERFORMANCE[4] DIFFERENCE	-3 seconds

[1]Mean crew loading time developed from data collected on both System I and System II as possess identical hopper design.

[2]Direct, stop watch measurement of crew time to load collection stops. In Queens, 23% of all stops made by System III constituted sample; 21% of all stops made by System I constituted sample. In Manhattan 35% sample used for System III; 38% sample for System I/II. Used regression program to compute averages.

[3]System III's route had on average two-tenths more items per stop than I.

[4]System III's route had 1.9 more items per stop, on average, than I/II.

- In District 63/Queens North, the productivity of each member of the 2-man crews exceeded that of each crewman on the 3-man crew. (See Table 13, page 31.)[7]
  - The median pounds of refuse loaded per crewman, per minute of on-route time, by each member of the 2-man crew exceeded his counterpart on the 3-man crew by 23.1%.

TABLE 13

CREWMAN PRODUCTIVITY AT DIFFERENT EQUIPMENT MANNING LEVELS
QUEENS NORTH/DISTRICT 63

CREWMAN PRODUCTIVITY MEASURES	CREWMAN PRODUCTIVITY		INCREASE IN CREWMAN PRODUCTIVITY 2-MAN CREW	
	TWO-MAN CREW (N=20)	THREE-MAN CREW (N=10)	PERCENT	POUNDS
Median Pounds Per Man Per Minute On-Route Time	17.17	13.95	23.1%	3.22
Median Pounds Per Man Per Hour On-Route Time	1,030.20	837.00	23.1%	193.20

- During the performance of refuse collection the 2-man crew made the following division of labor decisions: (see Table 14, page 32)
  - 75% of the stops, on average, were loaded by one-man, operating a collection truck with a cab specifically designed for quick egress and ingress by the second man performing the driving function.
  - The remaining refuse collection stops were loaded by the full two-man crew.
- During the performance of refuse collection the 3-man crew made the following division of labor decisions:
  - ZERO percent of the stops were loaded by 3 men.
  - ZERO percent of the stops were loaded by 1 man.
  - 100% of the stops were loaded by 2 men.

TABLE 14

CREW DIVISION OF LABOR
QUEENS NORTH/DISTRICT 63

EQUIPMENT SYSTEM	CREW SIZE	REFUSE STOP IN DISTRICT #63		LOADING FUNCTION[1]			DRIVING FUNCTION	
		WEIGHT	ITEMS	PERCENT OF STOPS LOADED BY 1 MAN	PERCENT OF STOPS LOADED BY 2 MEN	PERCENT OF STOPS LOADED BY 3 MEN	SHARED	EXCLU-SIVE
System I	2	30 pounds	2.25	62% to 89%	11% to 38%	no 3rd man available	Yes	
System III	3	33 pounds	2.45	0%	100%	0% with 3rd man available		Yes

[1]Sample size for System I was 15% of all stops during test period; sample size for System III was 15% of all stops during test period.

- - The workload characteristics of a stop in District #63 was such that the 3rd man on the 3-man crew never loaded, performing the driving function exclusively. (See Table 14, page 32.)

- - The 2-man crew, lacking a third man, shared the driving function with no increase in average loading time per stop.

- The average refuse collection stop in District #6/Manhattan East has the following loading performance related characteristics:

  - 6.6 refuse receptacles weighing 166.1 pounds.

    - 61% being one-way receptacles.

    - 37% being two-way receptacles.

    - 2% being bulk refuse.

  - Considerable obstacles between refuse location and vehicle in the form of single and double parked cars.

    - Cars parked bumper to bumper in many instances.

  - Refuse receptacles are not infrequently located flush against building facade, not on curb edge as in District 63.

- In District 6/Manhattan East, the performance difference as measured by mean crew loading time per stop was 3 seconds. (See Table 12, page 30.)[8]

  - 3-man crew loaded a refuse stop, on average in 69 seconds.

  - 2-man crew loaded a refuse stop, on average in 72 seconds.

- The 4.2% faster mean loading time achieved by the 3-man crew in District #6 was achieved with 50% more available crew-time per stop.[9]

- In District 6/Manhattan East, the productivity of each member of the 2-man crews exceeded that of each crewman on the 3-man crew. (See Table 15, page 34.)[10]

  - The median pounds of refuse loaded per crewman, per minute of on-route time, by each member of the two 2-man crews exceeded their counterparts on the 3-man crew by 16% to 31%.

TABLE 15

CREWMAN PRODUCTIVITY AT DIFFERENT EQUIPMENT MANNING LEVELS
MANHATTAN EAST/DISTRICT 6

CREWMAN PRODUCTIVITY MEASURES	CREWMAN PRODUCTIVITY			INCREASE IN CREWMAN PRODUCTIVITY 2-MAN CREW			
	TWO-MAN CREW LODAL 8 (N=14)	TWO-MAN CREW LODAL 12 (N=14)	THREE-MAN CREW HEIL MARK IV (N=14)	PERCENT		POUNDS	
				LODAL 8	LODAL 12	LODAL 8	LODAL 12
Median Pounds Per Man Per Minute On-Route Time	38.73	34.31	29.52	31.20%	16.23%	9.21 lbs.	4.79 lbs.
Median Pounds Per Man Per Hour On-Route Time	2,323.80	2,058.60	1,771.20	31.20%	16.23%	552.60 lbs.	287.40 lbs.

- In District 6/Manhattan East, the crews' division of labor appeared to reflect the greater workload presented by the refuse collection stop. (See Table 16, page 36.)

  - A sample measurement of stops revealed that, on average, 82.5% of these stops were loaded by both men on the 2-man crews.

  - More significantly, 41% of all refuse collection stops made by the 3-man crew were loaded by the full crew.

  - In comparison to the high frequency of one-man loaded stops in Queens North with the 2-man crew, only 17.5% of stops were loaded by one man on the two-man crews in Manhattan East.

It appears that each member of a two-man crew loads at a faster rate than the same on three-man crews regardless of the collection operating conditions as demonstrated during the field test period

- Queens North

  - Two-man crew 17.17 pounds per minute of on-route time.

  - Three-man crew 13.95 pounds per minute of on-route time.

- Manhattan East

  - Two-man crew 34.57 pounds per minute of on-route time.

  - Three-man crew 29.67 pounds per minute of on-route time.

TABLE 16

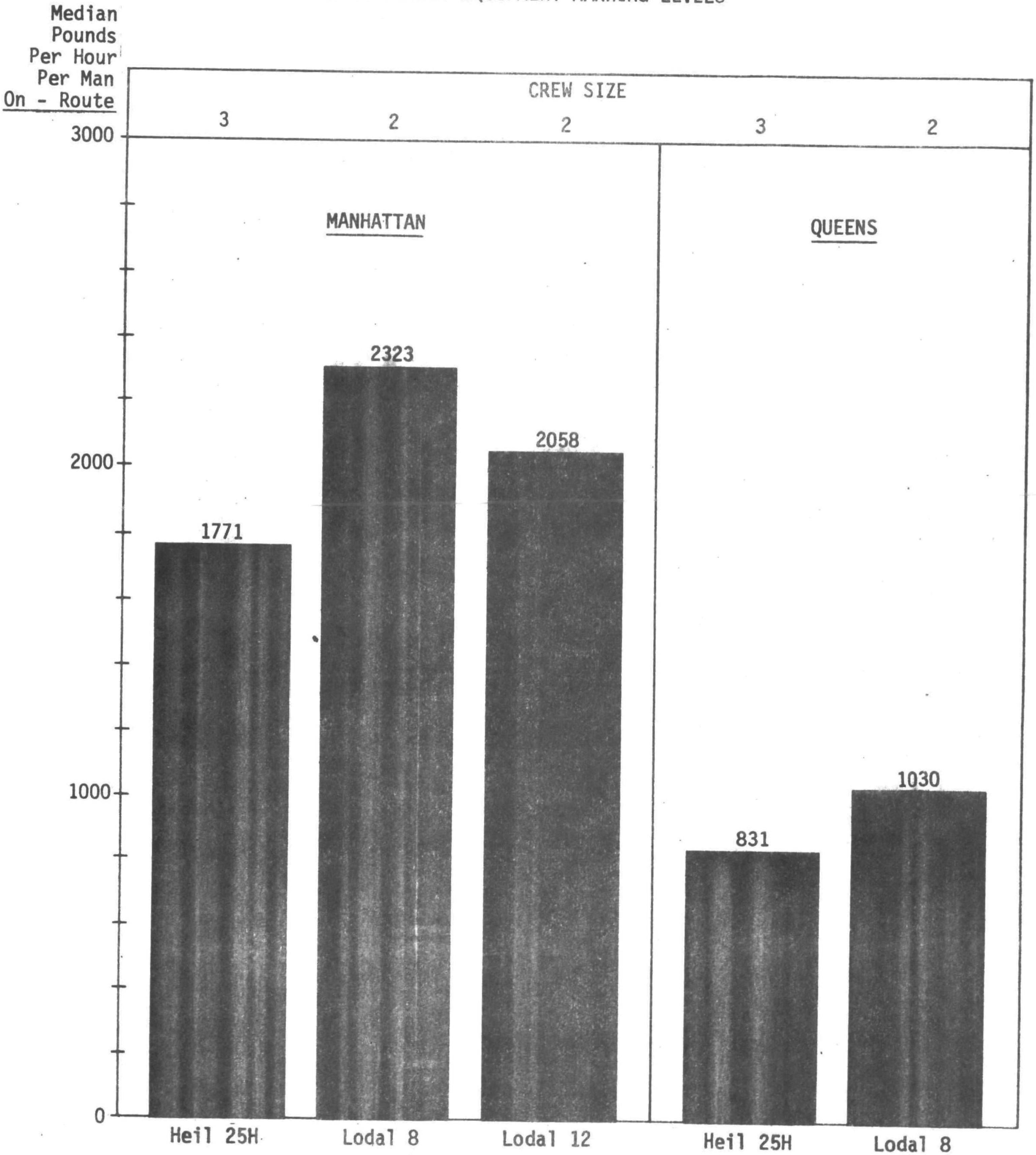
CREW DIVISION OF LABOR
MANHATTAN EAST/DISTRICT 6

EQUIPMENT SYSTEM	CREW SIZE	REFUSE STOP IN DISTRICT #6		LOADING FUNCTION[1]			DRIVING FUNCTION	
		WEIGHT	ITEMS	PERCENT OF STOPS LOADED BY 1 MAN	PERCENT OF STOPS LOADED BY 2 MEN	PERCENT OF STOPS LOADED BY 3 MEN	SHARED	EXCLU-SIVE
System I/II	2	146 pounds	5.97	17.5%	82.5%	no 3rd man available	Yes	
System III	3	205 pounds	7.88	0%	100%	41%	Yes	

[1]Sample size for System I/II 11% of all stops made during test; sample size for System III 12% of all stops made during test.

CHART I

CREWMAN PRODUCTIVITY
AT DIFFERENT EQUIPMENT MANNING LEVELS



VII. PROCEDURAL ANALYSIS: DISPOSAL AND REFUELLING

The full potential of the benefits to be derived from improved collection equipment can only be realized with improved operational procedures. Specifically, refuse disposal and refuelling operations were evaluated in conjunction with the equipment alternatives.

REFUSE DISPOSAL

The procedure currently used to dispose of collected refuse in District 63/Queens North results in an excessively high cost to transport refuse to a disposal location. The present practice is to dump the refuse well before the vehicle has reached its payload capacity. This represents an economically inefficient use of a capital resource.

- 23 disposal trips were made by the Heil Mark IV during the test period, at a total average cost of $810.08.
- The average payload per trip during the test period was 3.71 tons, representing an equipment utilization level per truck-shift of 47.9% of full capacity.
  - Average weight of the first truck load of a truck-shift was 5.16 tons, or 66.6% of capacity.
  - Average weight of the second load was 1.48 tons, or 19.1% of capacity.
- Under-utilization of equipment capacity resulted in an average disposal trip cost of $35.22, and an average disposal cost per ton of $9.45.

Reduction in total disposal cost can be achieved by eliminating the procedure of hauling of refuse to a disposal site before the full equipment capacity has been reached.

REFUELLING PROCEDURE (District 63/Queens North)

An operational analysis of the refuelling procedure in this District was undertaken because the refuelling depot and collection truck dispatch point are at two separate locations. At the completion of the 7-3 shift, the 4-12 garage shift at dispatch point 63A takes the trucks to the refuelling depot (District 63 garage). The round-trip is approximately 3 miles and takes 29.7 minutes.

- The total cost to refuel the Mark IV during the test period was $279.31, or $12.14 per refuelling trip.

- The cost of transporting the vehicles to the refuelling depot and back to the dispatch point--exclusive of the cost of the fuel--for the 8,343 collection runs made in District 63 during Fiscal Year 1975-76 was estimated at $101,317.40.

- This expenditure could have been used by the Department of Sanitation to purchase 259,123.79 gallons of regular fuel, at .391¢ per gallon, or enough fuel for 13,032 collection runs (the number made in approximately 1.5 years) in District 63.

VIII. NON-EQUIPMENT RELATED PRODUCTIVITY FACTORS

The Uniformed Sanitationmen's Association's contract allows 85 minutes per truck-shift for the non-work activities of check-in, work-breaks, lunch and wash-up. Analysis of the test period data for System III revealed the following:

- In District 63/Queens North, actual time used for work relief activities was 137.5 minutes, exceeding the allowed time by 51.5 minutes per truck-shift or 61.6%.[11]
    - Actual work-break time exceeded allowed time by 6.5 minutes or 21.7%.
    - Actual lunch time exceeded allowed time by 30 minutes or 100%.
    - Actual wash-up time exceeded allowed time by 15 minutes or 100%.
- In District 63/Queens North, current under-utilization of truck-shift time reduced the available work period by 14.9%, from 344 minutes to 292.5 minutes per truck-shift, resulting in:
    - 15.7% or 1.13 fewer tons collected per truck-shift during the test period.
    - 18.6% more truck-shifts deployed during the test period.
    - 18.6% increase in the cost of collecting refuse on the test routes.
- In District 6/Manhattan East, actual time used for work relief activities was 143.5 minutes, exceeding the allowed time by 58.5 minutes per truck-shift or 68.8%.[12]
    - Actual check-in time exceeded allowed time by 9 minutes or 90.0%.
    - Actual work-break time exceeded allowed time by 17 minutes or 56.7%.
    - Actual lunch time exceeded allowed time by 24.5 minutes or 81.7%.
    - Actual wash-up time exceeded allowed time by 18 minutes or 120.0%.

- In District 6/Manhattan East, current under-utilization of truck-shift time reduced the available work period by 18.3%, from 320.0 minutes to 261.5 minutes per truck-shift, resulting in:
  - 19.0% or 2.71 fewer tons collected per truck-shift during the test period.
  - 23.5% more truck-shifts deployed during the test period.
  - 23.5% increase in the cost of collecting refuse on the test routes.

Reduction in the available truck-shift work period by 14.9% in District #63 and by 18.3% in District #6 and actual time used for non-work activities exceeding the allowed time by 61.8% and 68.8% respectively, results in excessive truck-shift deployment and collection expenditure levels. Projected performance and cost improvements with retrieval of the currently lost truck-shift work-time in command zones presenting similar collection operating conditions would be large:

- Projected reduction in total truck-shifts deployed, in command zones Queens North, Queens South, Queens West, Richmond, Manhattan East and Manhattan West, to collect Fiscal Year 1976 refuse workload could have been 28,070 truck-shifts.

- Projected cost reduction in the collection of refuse in these command zones for Fiscal Year 1975-76 could have been $13.883 million. (Cost per truck-shift as obtained during the field test includes labor and equipment costs.)

IX. RECOMMENDATIONS

VEHICLE DESIGN COMPONENTS (See Map 1, page 42.)

The virtually homogenous refuse collection fleet of New York City's Department of Sanitation should be diversified to achieve a better fit between collection environment and apparatus. This could be done by:

- Using side-loading mid-ship positioned hoppers in areas where refuse collection stops are similar to those in the Queens North test area:
  - Areas with a significant number of one-way refuse receptacles.
  - Where the one-way receptacles are light weight.
  - Where curbside and street is relatively unobstructed.
- Using rear loading hoppers in areas where refuse stops are similar to those in the Manhattan East area:
  - Areas with a significant number of compacted one-way receptacles.
  - Where the weight of one-way receptacles are such that they have to be placed rather than tossed into the hopper.
  - Where curbside and street are obstructed by such obstacles as single and double parked vehicles.
  - Where vehicular flow is heavy.
- Making step-in/step-out cabs standard on all City collection vehicles to reduce egress time and to prevent driver from possibly exiting cab into the flow of traffic.

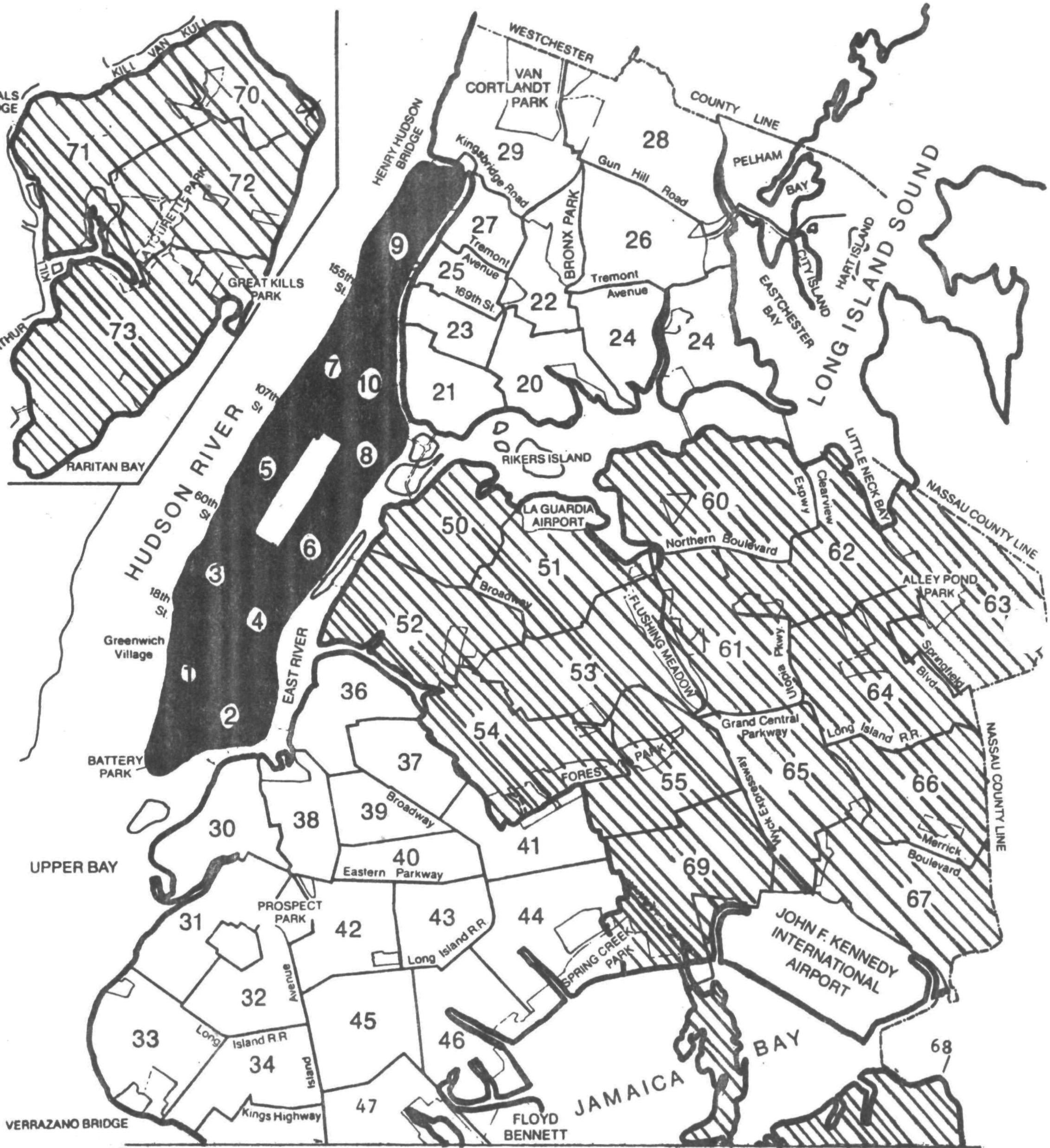
PAYLOAD CAPACITY

Purchase vehicles with a payload rating of 10 tons tó be deployed in long-haul disposal areas such as Queens North.

- Ensure full utilization of payload capacity of all collection vehicles through special training of field management--District Supervisors, Section Foremen and Assistant Foremen.

MAP 1

DEPLOYMENT AREAS FOR NEW TYPES OF COLLECTION VEHICLES



Hatched	2 Man Crew/Side Loading Hopper/Step-In Step-Out Cab/10 Ton Payload
Solid	3 Man Crew/Rear Loading Hopper/Step-In Step-Out Cab/Current Payload (plus)

- - Institute a 6.6 ton actual capacity value that should be used to trigger a disposal trip for the Heil Mark IV 25H truck.
  - Institute a 10 ton capacity value that should be used to trigger a disposal trip for vehicles with such capacity.

- Develop a specification quality control program to insure that vehicles purchased by the City meet values (within pre-determined tolerances over life of vehicle) indicated on specification documentation, primarily as it pertains to payload rating.

REFUELLING PROCEDURE

- Install a refuelling capability at garage 63A ("Ponderosa"), or, alternatively, share the fuel pumps used by the Department of Highways located next door.

EQUIPMENT MANNING LEVELS

- Consideration should be given to the deployment of 2-man collection crews on the vehicles currently in use, as well as on larger payload vehicles with vehicle components as discussed, in Command Zones Queens North, South, West and Richmond. The daily work output target should be equivalent to the 9.12 tons per truck-shift achieved by the three-man crews in Fiscal Year 1976; with per man-day performance level increased from 3.04 tons to 4.56 tons. (See Table 17, page 44 for comparison or recommended man-hour output target and actual man-hour outputs achieved in other municipalities.)

- Consideration should be given to the deployment of 3-man crews in Command Zones Manhattan East and West, to operate 20 cubic yard collection vehicles with step-in/step-out cabs and attain an increase in daily work output. The Fiscal Year 1975-76 standard of 11.35 tons per truck-shift and 3.78 tons per man-day indicate underperformance by 3-man crews. It should be possible for a 3-man crew to handle 16.32 tons per truck-shift and 5.44 tons per man-day. (See Table 18, page 44 for comparison of recommended man-hour output target and actual man-hour outputs achieved in other municipalities.)

NON-EQUIPMENT RELATED PRODUCTIVITY FACTORS

- Truck-shift work periods be restored to the level paid for by the City and called for in Union contracts.

TABLE 17

—TWO-MAN CREWS—
RECOMMENDED MAN-HOUR PERFORMANCE
vs.
ACTUAL MAN-HOUR PERFORMANCE ACHIEVED
IN OTHER MUNICIPALITIES

MUNICIPALITY	TONS PER MAN-DAY	TONS PER MAN-HOUR
New York City		
- Current	3.04	.62
- Recommended	4.56	.80
Flint, Michigan	7.25	1.55
Rockford, Illinois	6.31	1.31
Tuscon, Arizona	3.48	.84
AVERAGE		1.23

TABLE 18

—THREE-MAN CREWS—
RECOMMENDED MAN-HOUR PERFORMANCE
vs.
ACTUAL MAN-HOUR PERFORMANCE ACHIEVED
IN OTHER MUNICIPALITIES

MUNICIPALITY	TONS PER MAN-DAY	TONS PER MAN-HOUR
New York City		
- Current	3.78	.87
- Recommended	5.44	1.02
Warwick, Rhode Island	4.22	1.08
Dade County, Florida	4.70	1.07
AVERAGE		1.075

- 344 minutes or a 18% increase in work time per truck-shift in Queens and Richmond.

- 320 minutes or a 22% increase in work time per truck-shift in Manhattan East and West.

- Operational accountability for achieving truck-shift output targets and work periods should be assigned to Zone Commanders.

- Design and implementation of improved routing to achieve output targets, collection equipment diversification programming and automated performance control system be a joint venture of Headquarters staff and Zone Commanders.

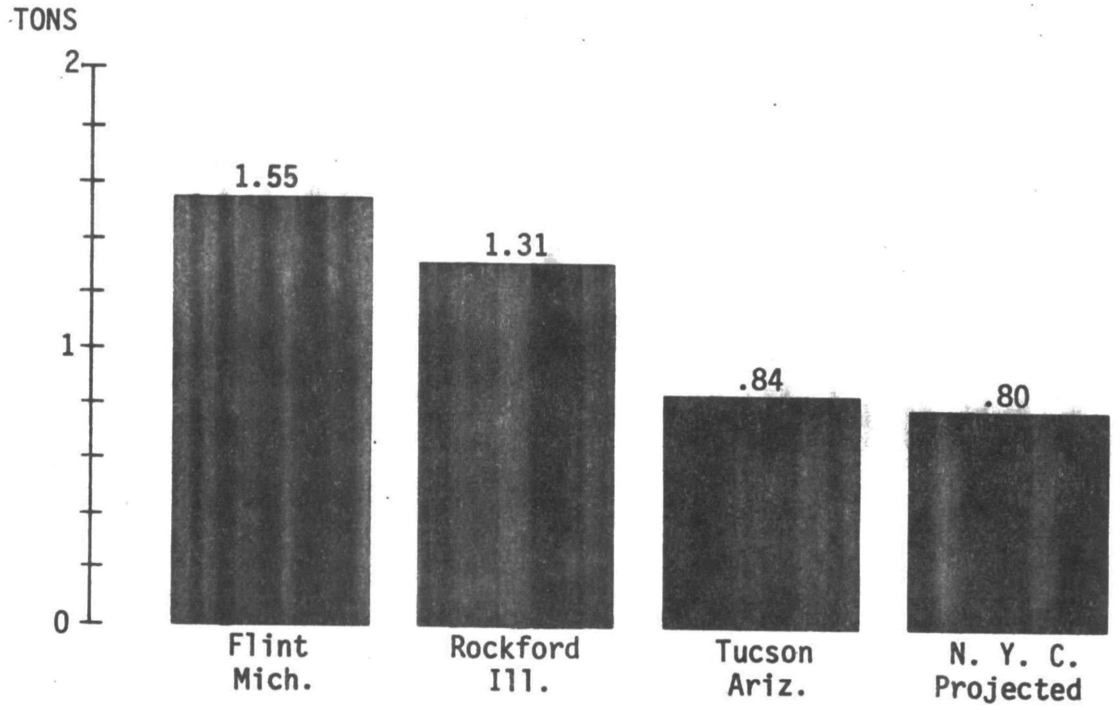
- Along with operational accountability for target achievement, command authority be lodged with the Zone Commanders for control over resources to achieve same and to take corrective action against Districts not performing at target.

ASSIGNMENT OF COLLECTION VEHICLES

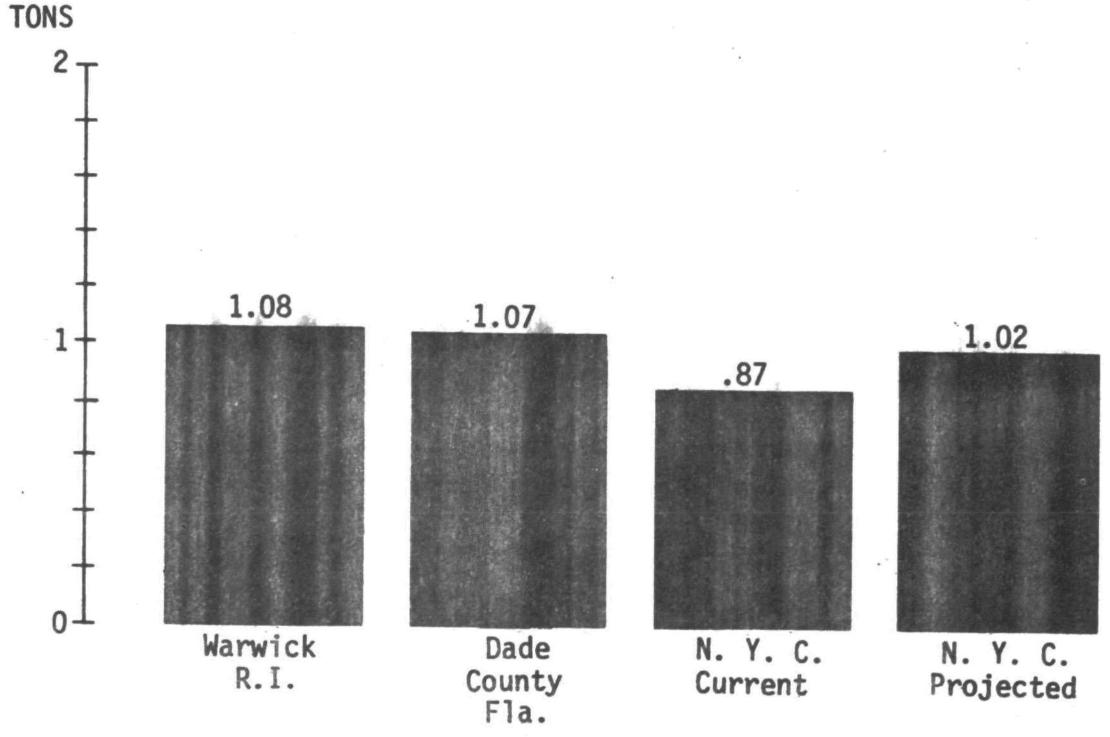
- Explore possibility of the permanent assignment of a collection vehicle to a crewman.

CHART II

TONS PER MAN HOUR - TWO MAN CREWS



TONS PER MAN HOURS - THREE MAN CREWS



X. PROJECTED COST BENEFITS

COMPARATIVE CAPITAL INVESTMENT REQUIRED TO PURCHASE 10 TON PAYLOAD CAPACITY TRUCKS AND NEW FLEET OF HEIL MARK IV TRUCKS

- At an approximate cost of $34,040 per vehicle, the 784 Heil Mark IV collection trucks that might be required by the 20 sanitation Districts of Command Zones Queens North, South, West and Richmond would have a replacement cost of $26.689 million.

- At an approximate cost of $48,000 per vehicle, the 458 10-ton collection trucks that might be required by the same 20 sanitation Districts would have a replacement cost of $21.984 million.

- The projected reduction in replacement costs achieved through the acquisition of 10-ton collection vehicles would be $4.705 million.

- Deployment of a refuse collection vehicle with a rated payload capacity of 10 tons, despite an estimated cost of $48,000 per vehicle, would have resulted in the projected reduction in the number and cost of disposal trips in these Command Zones in Fiscal Year 1975-76 of as much as:

  - Total estimated trips would have been 106,798, down 54% over the 232,744 trip level.

  - Total estimated disposal cost would have been $4.1 million, down $4.1 million or 50%.

SAVINGS FROM INSTALLATION OF INCREASED CAPACITY VALUE DISPOSAL TRIGGER

If disposal during the test period in Queens North had been triggered at 6.6 tons and not before, the costs would have been:

- $456.87 to complete 13 disposal trips and haul 85.75 tons of refuse.

  - This represents a 43.6% estimated reduction in total disposal frequency and cost with virtually no implementation or recurring procedural expenditures.

  - Payback period for this operational change would have been almost immediate.

- The cost of disposing of a ton of refuse would have declined by 43.6%, or from $9.45 to $5.33--a figure which is less than System I's disposal cost of $5.62 per ton.

If disposal had been triggered at 6.6 tons for Fiscal Year 1975-76 in Queens North, South, West and Richmond, similar savings would have resulted. Instead of the mean payload per disposal trip being 4.51 tons at a cost of $8.197 million:

- Total estimated trips would have been 161,813, down 30.5%.

- Total estimated disposal cost would have been $5.699 million, down $2.498 million or 30.5%.

MANNING LEVEL (See Map 2, page 48.)

Based on the performance analysis of 2- and 3-man crews conducted during the field test and Fiscal Year 1975-76 truck-shift deployment levels for Queens North, South, West and Richmond, the following cost projections were developed:[13]

- Refuse collection costs at current equipment manning level for Fiscal Year 1975-76 was $53.3 million to collect 1,067,906 tons of refuse with 117,118 truck-shifts.

  - Actual average performance level with current crew size was 9.12 tons per truck-shift and 3.04 tons per man-day.

- Refuse collection costs with reduced equipment manning to two-man crews (operating the current System III vehicle) for Fiscal Year 1975-76 would have been $37.2 million to collect same amount of refuse with same number of truck-shifts--a projected cost reduction of $16.1 million.

  - Performance level would have been 9.12 tons per truck-shift and 4.56 tons per man-day.

Manhattan East and West deployed 50,969 truck-shifts during Fiscal Year 1976 at an estimated cost of $21.97 million.[13]

- By retrieving documented lost work time an additional 2.61 to 2.73 tons, or, 23.4% more refuse can be collected per truck-shift.

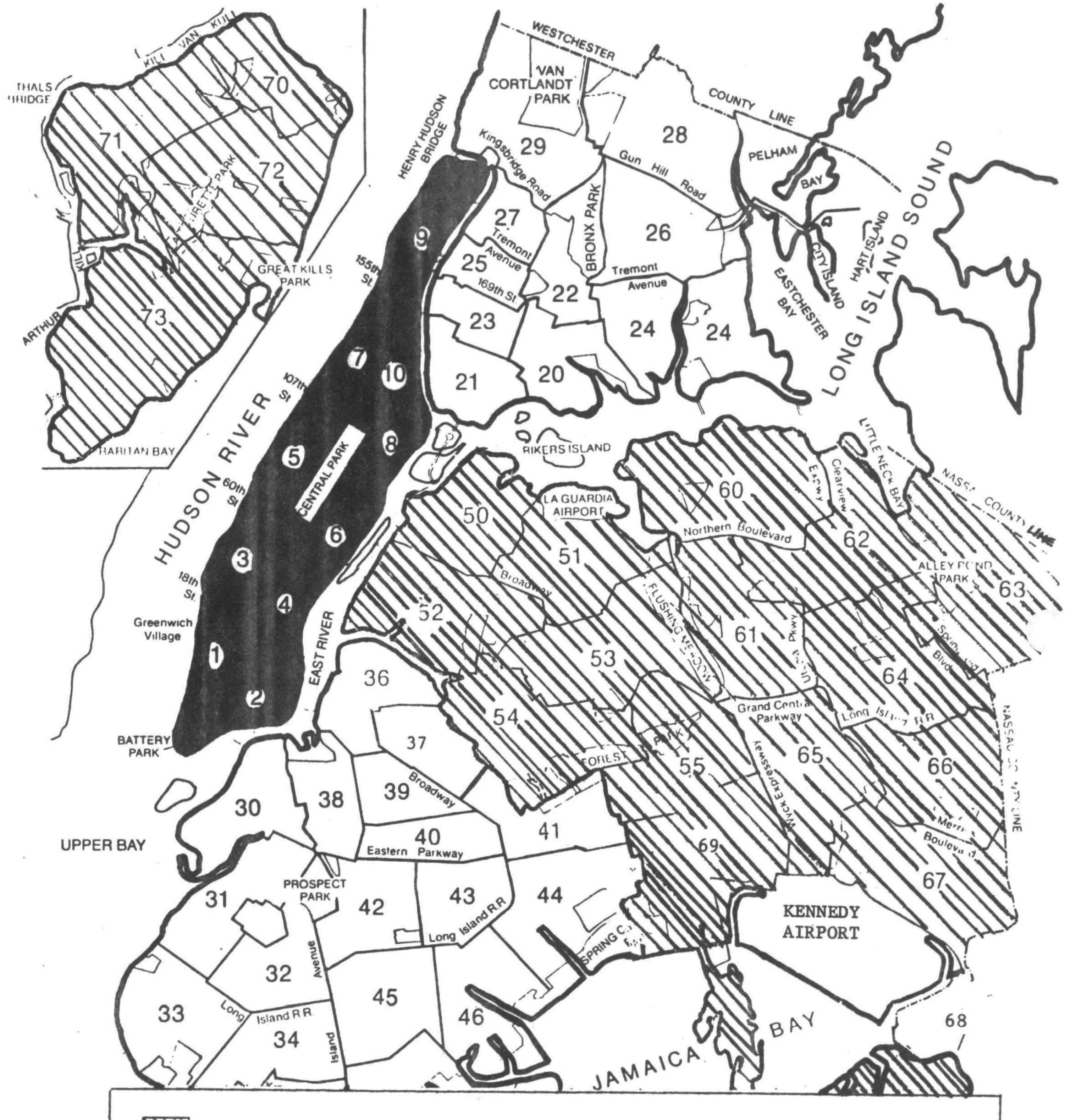
- By increasing crew loading rate by 20.38%, an additional 2.27 to 2.37 tons can be collected per truck-shift.

- According to these realizable gains, only 35,434 truck-shifts would have had to be deployed instead of 50,969 with a savings projected at $6.69 million.

MAP 2

$22.8 MILLION REDUCTION IN COLLECTION LABOR COST

-Estimated For FY 1976-



2 Man Crews/4.56 Ton Per Man-Day/$16.1 Million Labor Saving/FY'76(est.)

3 Man Crew/5.44 Tons Per Man-Day/$6.7 Million Labor Saving/ FY'76(est.)

ATTACHMENT A

FOOTNOTES

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Footnote #1: Cost-per-ton, as computed by manufacturer of System I, corroborates FCNY finding that the System is more costly than System III: unit cost of System I is $69.76, versus $66.24 for System III (5.04% less per ton). Differences in dollar value result from different cost accounting procedures, but both sets of data indicate the same unit cost relationship: System III is less expensive.

Footnote #2: Field tests cannot control for all contingencies in the collection environment, but an output measure was designed to equalize the difference in workloads (number of refuse receptacles per stop) found on different routes in the same test area. The rationale behind the workload equalization procedure was that while individual route workloads differ slightly, each is representative of the collection conditions which prevail in a given area. Subsequently, when a unit cost for each System was derived, a cost comparison could be made, based on actual field performance against equivalent workloads. Equalization measures were applied to Queens and Manhattan collection stop output data.

Footnote #3: The manufacturer's cost per stop findings differ from those of the Fund because the manufacturer did not adjust for unequal workloads and the Fund did. In this instance the two sets of findings do not vary significantly because the actual workloads were relatively similar (one-tenth fewer receptacles on System I's route than System III): unit cost per stop for System I, as computed by manufacturer, was 1% less than for System III; Fund's unit cost was 0.27 of a percentage point less. When actual workloads show greater variations, as they did in District 6, unit costs will be skewed to the lighter route if the equalization procedure is not applied.

Footnote #4: Important variations exist between the values obtained by the Fund and those claimed by the manufacturer for total tons collected by System III for the test period: 85.75 (FCNY) versus 81.63 (manufacturer); average tons per truck-shift: 6.13 (FCNY) versus 5.84 (manufacturer). The discrepancies can be accounted for by the sometimes arbitrary methodology used by the manufacturer. While some of their "corrections" and "adjustments" seem valid, others do not. For example, for 8 of the 9 second load payloads on System III, they decreased the weight, something they did not do for System I although both were weighed in the same manner. There seems to be the assumption that if the average weight of a refuse item is greater on the second load than the first, the second load weight is incorrect. No test was conducted to determine if the difference in average weight was random or statistically significant. Yet given that both loads were weighed in the same manner, it would have been equally reasonable to assume that the first load averages were too small.

Footnote #5: Cost per ton as computed by manufacturer of Systems I and II corroborates FCNY finding that they are more costly per ton than System III; 10% and 7% respectively.

Footnote #6: No comparison of this value is possible since the manufacturer did not separately measure loading time or travel time between stops. Measurement was of combined <u>collection rate</u>: time to load plus time to travel between stops. However, the manufacturer's average collection rate--32.1 seconds for System III and 35.7 seconds for System I--indicates that the 50% greater manning level of the former did not result in a commensurate increase in performance. FCNY's value of 19 seconds for both systems suggests a similar conclusion. Both sets of findings validate the potential feasibility of 3-man crews in <u>only</u> certain areas of the City. Further, they strongly suggest that a mid-ship positioned hopper can be a beneficial vehicle design feature.

Footnote #7: Median pounds of refuse loaded per crewman per minute of on-route time as measured by manufacturer yielded a comparable figure of 23.6%.

Footnote #8: Comparative data not available, as per footnote #3. As measured by the manufacturer, the average collection rate for System II was 111.4 seconds and for System III 106.8 seconds. The percentage difference between these values and the percentage difference between FCNY's values for the loading rates of these Systems are almost equivalent:

4.1% and 4.2%. Both sets of data raise the issue of the benefits of going from a 2-man to a 3-man crew. In addition, the average collection rate, as measured by the manufacturer, for System I was 87.8 seconds, or 17.7% faster than System III's 106.8 second.

Footnote #9: Both sets of data for Districts 63 and 6 indicate that the return on a 50% greater labor investment, whether measured as collection rate or loading rate, does not produce a corresponding increase in performance.

Footnote #10: Comparative crewman productivity as measured by the manufacturer corroborates FCNY's findings that productivity is greater for the smaller crews of Systems I and II. Both sets of data identify System I's crewmen as loading faster than those on System II and III. Specific values of how much faster differ--16.3% (manufacturer) versus 31% (FCNY). Similarly, System II's crewmen loaded faster than System III, again with different specific values--2.1% (manufacturer) versus 16% (FCNY).

Footnote #11: Crew time utilization data collected by the manufacturer of System I and the Load-A-Matic yielded a comparable median figure: 147.0 minutes for non-work activities per System III truck-shift.

Footnote #12: Crew time utilization data collected by the manufacturer of System I, II and the Load-A-Matic yielded a comparable median figure: 158.5 minutes for non-work activities per System III truck-shift.

Footnote #13: Cost components of projections are sanmen and section foremen man-days and a post coverage factor of .5 per man-day.

Sanman man-day cost computed at:

$309.80	base pay for five day week for three-year man
+ 147.93	for fringes at 47.75% rate
$457.73	per week
x .50	post coverage factor
$228.87	
+ 457.73	
$686.60 ÷ 5 = $137.32	to put one sanman in the field for one day.

Supervision man-day cost is $161.955:

approximate annual salary $19,000

$365.38	base pay for five day week
+ 174.47	for fringes at 47.75% rate
$539.85	per week
x .50	post coverage factor
$269.93	
+ 539.85	
$809.78 ÷ 5 = $161.955	to put one supervisor in the field for one day to cover 3 to 5 routes in Queens North; 8 to 9 routes in Manhattan East.