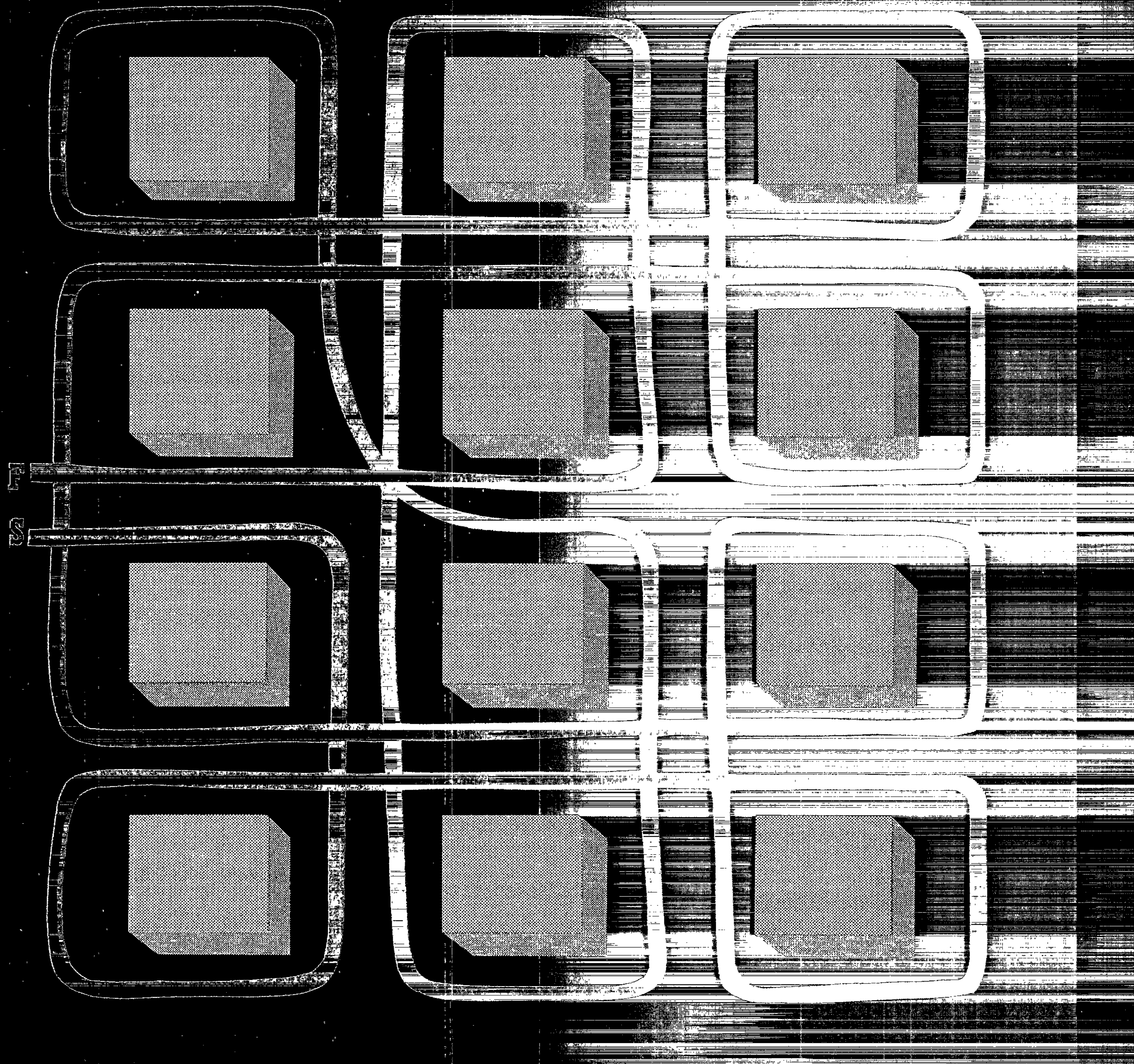
HEURISTIC ROUTING

FOR SOLID WASTE COLLECTION VEHICLES



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This publication (SW–113) was written
for the Federal solid waste management programs
by KENNETH A. SHUSTER and DENNIS A. SCHUR

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FOREWORD

The collection of solid wastes generally represents from 70 to 80 percent of a community's total waste management costs. To help reduce these costs, and at the same time improve the quality of community services, over the past several years EPA's Office of Solid Waste Management Programs has been conducting studies on solid waste storage and collection systems. This report on heuristic routing is the first of a series of reports documenting the studies. Others will include:

- A Five-Stage Improvement Process for Solid Waste Collection Systems
- Management Information System for Residential Solid Waste Collection
- Policies and Methodologies for Solid Waste Collection
- Districting and Route Balancing

Additional projects are under way or planned that ultimately will complement this information. These include studies on: rural storage and collection systems; inner-city storage and collection systems; financial mechanisms for both capital and operating expenses; institutional and organizational arrangements, ranging from public collection systems to open and free private competition working within various regulatory and utility structures.

All the studies and resultant reports have two major purposes: (1) to provide information or guidelines on the many possible alternatives for storage and collection systems; (2) to provide relatively simple, but effective, solid waste management tools for evaluating the systems. These management tools are designed to measure the effectiveness and efficiency of the various kinds of storage and collection systems, to identify high cost centers in the systems, and to provide predictive information on the effect of changes in the systems.

The objectives of a storage and collection system should be to provide service that is economical, that is environmentally sound, that is aesthetically acceptable, and that assures a continuity in service. These same objectives also are the underlying measures of storage and collection effectiveness used in developing the guidelines and the management tools.

—ARSEN J. DARNAY
Deputy Assistant Administrator
for Solid Waste Management

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HEURISTIC ROUTING FOR SOLID WASTE COLLECTION VEHICLES

what is the heuristic approach to problem solving?

The heuristic approach to problem solving consists of applying human intelligence, experience, common sense and certain rules of thumb (or heuristics) to develop an acceptable, but not necessarily an optimum, solution to a problem. Of course, determining what constitutes an acceptable solution is part of the task of deciding what approach to use; but broadly defined, an acceptable solution is one that is both reasonably good (close to optimum) and derived within reasonable effort, time, and cost constraints. Often the effort (manpower, computer, and other resources) required, the time limits on when the solution is needed, and the cost to compile, process, and analyze all the data required for deterministic or other complicated procedures preclude their usefulness or favor the faster, simpler heuristic approach.

Thus, the heuristic approach generally is used when deterministic techniques or mathematical models are not available, economical, or practical. Its use, according to Bowman and Fetter, predominates in at least three circumstances:

1. Where problems are so complex that, though the essence of the problem may be stated in a mathematical framework, the computation required is quite unfeasible, even on the largest computer.
2. Where problems—especially policy problems with which top managers must grapple—are so amorphous that a mathematical model cannot capture their most important characteristics.
3. Where, although a mathematical model may be successfully employed, the prelude to the model and the work subsequent to the modeling must be of a less formal nature.[1]

Most complex problems encountered in the real world fall into one or more of the preceding categories and often can be solved through the use of heuristics. Or, frequently the most economical and practical approach is a combination of rigid models and heuristics.

what is routing?

The term routing has been applied to solid waste management in several different ways. As a result, several models or approaches to solid waste routing have been developed, each of which addresses itself to a very different problem. The problems, or models, may be divided into three categories: macro-routing, districting and route balancing, and micro-routing (Figure 1).

Macro-routing determines the assignment of daily collection routes to existing processing and disposal sites. The objective is to optimize the use of processing and disposal facilities in terms of the daily and long-range capacities and operating costs of the facilities, while minimizing the round trip haul time (and hence the hauling cost) from the collection routes to the processing or disposal sites. Information essential to macro-routing includes haul times from the routes to the various processing and disposal sites, crew size and vehicle capacity, expected arrival, queue, and service times at the sites, and short- and long-range capacities and costs of the sites. Macro-routing may also be useful in determining which of several proposed processing and disposal sites or garage locations is most economical, again by considering such factors as costs, site capacities, and

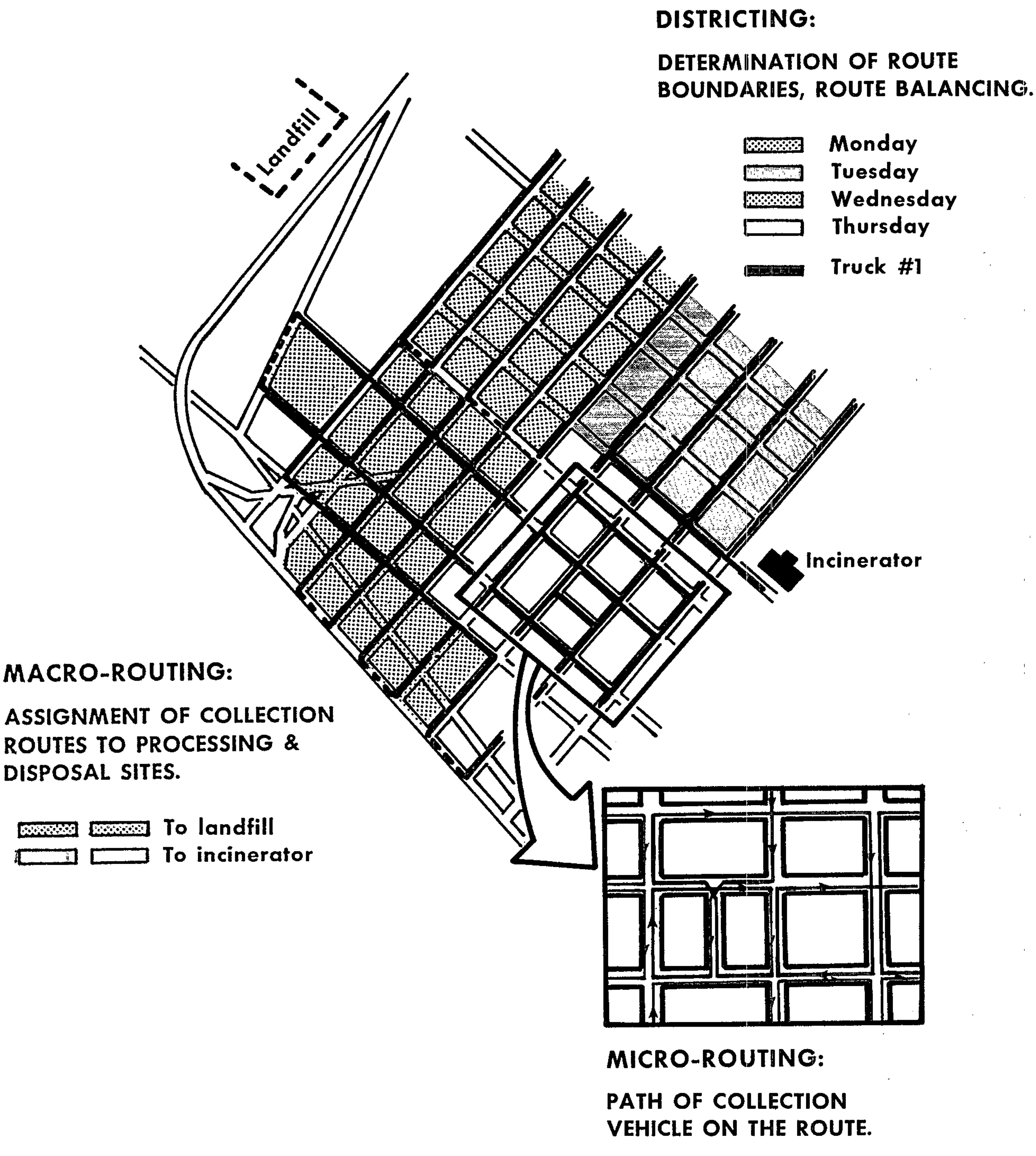

Figure 1. Types of routing: (1) macro-routing is assigning collection routes to processing and disposal sites; (2) districting is determining route boundaries and route balancing; (3) micro-routing is determining the path of collection vehicles on the route. The heuristic approach described in this report applies to micro-routing.

round trip haul times.

Districting and route balancing determines a fair day's work and divides the collection areas into balanced routes so that all crews have equal workloads. This is achieved through a careful evaluation of how the collection crew spends its time.

Micro-routing looks in detail at each daily collection service area to determine the path that the collection vehicle should follow as it collects from each service on its route. The objective is to minimize the driving time on the collection route through minimizing the dead distance (i.e., street segments that have no services or that are traversed more than once), backing of vehicles, U-turns, left turns, collection on major streets during rush hour traffic and other delay times.

why a heuristic approach to micro-routing?

Traditionally there are three approaches to problem solving: deterministic, heuristic-deterministic, and heuristic.

The deterministic approach would seek to solve the micro-routing problem by developing a mathematical model. This model would always determine the optimum route based upon the required input data. To date, no completely deterministic models have been developed. That is, there are no models that consider all the factors pertinent to routing and that guarantee the optimum solution through eliminating all other possible alternatives. There are three major reasons for this. First, it is too difficult to quantify all the pertinent factors. Second, it would be prohibitively costly and time-consuming to investigate all the possible solutions, even with a computer model. And third, the collection route itself is subject to so many dynamic variables that the optimum solution may change frequently.

As applied here the heuristic-deterministic approach attempts to solve the micro-routing problem by using a computer to examine many possible alternatives and select the best alternative based on some heuristic algorithm. In applying any of the computer models currently being marketed, the user (typically a consultant) must spend time becoming familiar with the community, preparing information for computer input, and adjusting and debugging the computer program to perform the necessary computations for each specific community. The computer input includes information required to develop an elaborate node system defining the street network of the community (Figure 2) and the characteristics of each street segment; e.g., the length of the street and the number of services between nodes; traffic patterns; and the quantity of waste generated.

The heuristic approach deals with the micro-routing problem by using a manual procedure to develop acceptable collection routes without examining many possible alternatives. It is certainly possible to develop a good solution to the micro-routing problem using either the heuristic-deterministic computer models or the manual heuristic approach.

The manual heuristic approach, however, has some distinct advantages over the computer models. It is faster, less costly, more flexible, and easier for local personnel to apply. The manual heuristic approach requires less data preparation than the computer models by eliminating several such time-consuming tasks as preparing information for computer input, developing a node network, and modifying the computer program.

The computer is a powerful and useful tool, but in the case of micro-routing, a man can often perform the task more economically. For example, it is easy for a person to read a map, but difficult to program a computer to do so. Heuristic rules are relatively easy for an experienced person to apply while considering a variety of street and traffic peculiarities, compared to the difficulty and cost of programming. It is also relatively easy for a person to add or modify a rule for a specific situation, or to modify a route at a later date, compared to rewriting programs, punching new data cards, and rerunning a computer model. Municipal personnel can readily understand the basis for routings done manually—a real advantage in implementing, in conducting daily operations, and in making necessary modifications as conditions change.

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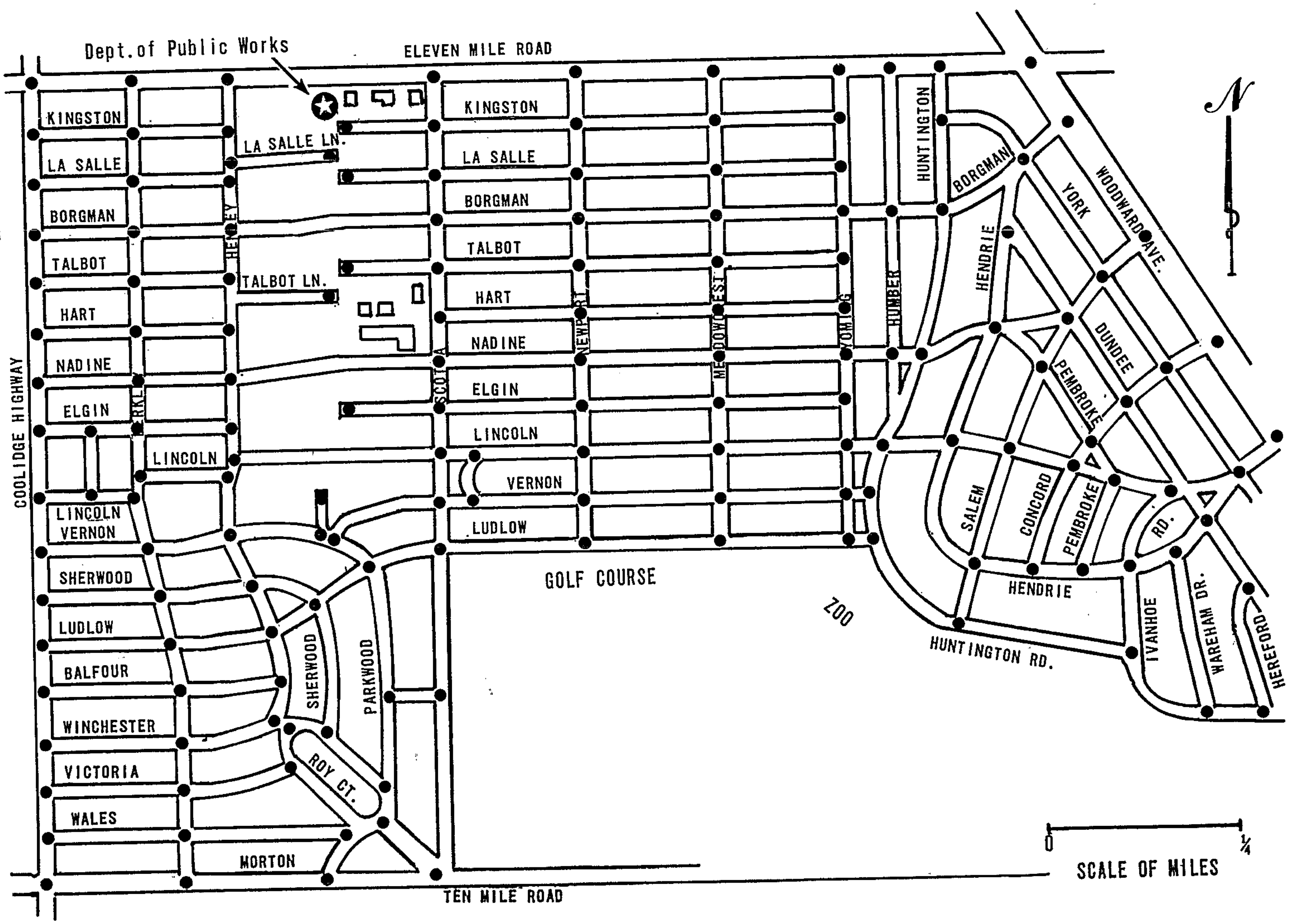


● DESIGNATES NODES TO BE PROGRAMMED

Figure 2. A computer model would require 162 nodes for Huntington Woods, Mich.

MICRO-ROUTING -WHY AND WHEN

what is the value of micro-routing?

The value of micro-routing becomes obvious when one considers the repetitive nature of the collection process: any time saved by reducing collection route distance and travel delays becomes cumulative. Assume, for example, that a community has 10 trucks, each with a three-man crew that services 450 residences daily in about 4 hours of on-the-route collection time. If 24 minutes of collection time per crew can be saved by rerouting, then nine collection routes can service the same areas without taking more than the original 4 hours by adding 50 services to each route. The total savings represent one collection vehicle and three man-years of labor (one crew). To realize these savings, these 24 minutes per route must, of course, be utilized through further rerouting and route expansion or through a change in crew size, rather than dismissing the collectors 24 minutes earlier each day. The larger the collection system (i.e., number of crews) the greater is the absolute savings potential.

when should it be used?

In many communities the existing collection routes have evolved as the communities have grown, by sporadically adding a section here and there to the various routes, or adding new routes to the new areas. Rarely has the overall route structure been periodically examined. Thus many communities have fragmented, overlapping, or unbalanced routes that have unnecessary dead distance, delay times, and inequitable workloads. If this is the case, micro-routing should be used.

Rerouting is also needed whenever there is a significant change in the collection system. Such changes include: frequency of collection; point of collection (curbside, alley, or backyard); crew size; truck size or equipment type; location of disposal sites; type of storage container [209-liter (55-gal) drums, cans, sacks, etc.]; combined versus separate waste collection; or number of services. In case of a change in disposal sites, macro-routing should precede micro-routing to determine round trip haul time for each route.

HEURISTIC APPROACH TO MICRO-ROUTING

The heuristic approach to routing is a relatively simple and expedient method for obtaining an efficient route layout that minimizes dead distances and delay times. The heuristic approach could also be called the pattern method of routing since it relies heavily on the application of specific routing patterns to certain block configurations. Admittedly, efficient routing requires both skill and aptitude. But guided by certain heuristic rules and patterns, and through experience, a router can readily develop the ability to scan a map and rapidly and systematically plot timesaving routes.

what are the heuristic rules for micro-routing?

1. Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.

2. Total collection plus haul times should be reasonably constant for each route in the community (equalized workloads).

3. The collection route should be started as close to the garage or motor pool as possible, taking into account heavily traveled and one-way streets. (See rules 4 and 5.)

4. Heavily traveled streets should not be collected during rush hours.

5. In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process (Figure 3).

6. Services on dead end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep left turns at a minimum, collect the dead end streets when they are to the right of the truck. They must be collected by walking down, backing down, or making a U-turn.

7. When practical, steep hills should be collected on both sides of the street while vehicle is moving downhill for safety, ease, speed of collection, and wear on vehicle, and to conserve gas and oil.

8. Higher elevations should be at the start of the route.

9. For collection from one side of the street at a time, it is generally best to route with many clockwise turns around blocks.

Heuristic rules 8 and 9 emphasize the development of a series of clockwise loops in order to minimize left turns, which generally are more difficult and time-consuming than right turns and, especially for right-hand-drive vehicles, right turns are safer.

10. For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping clockwise.

11. For certain block configurations within the route, specific routing patterns should be applied.

what routing patterns should be applied?

As the router gains experience, he will recognize routings that are efficient for certain block patterns. Certain patterns should be considered whenever the grid has blocks arranged as shown in the figures (Figures 3 through 7). Sequential application of these patterns helps

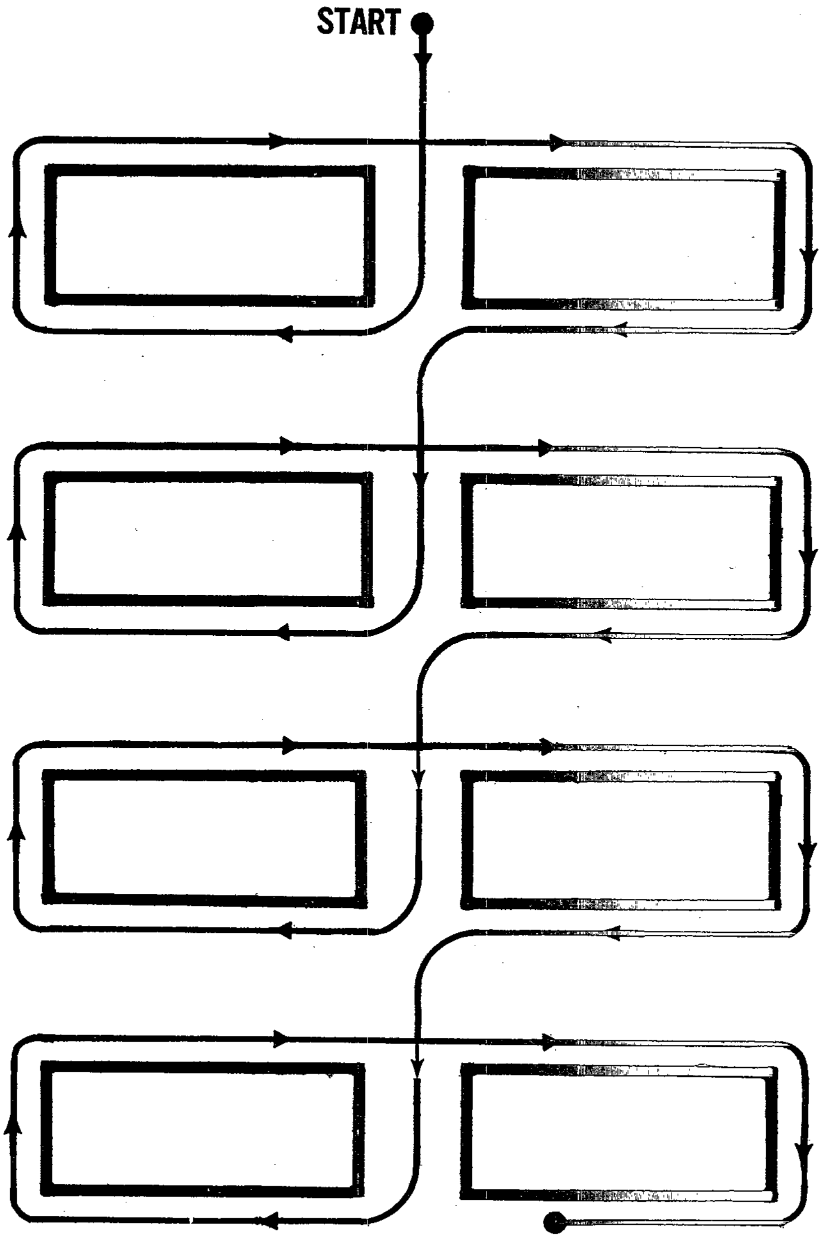
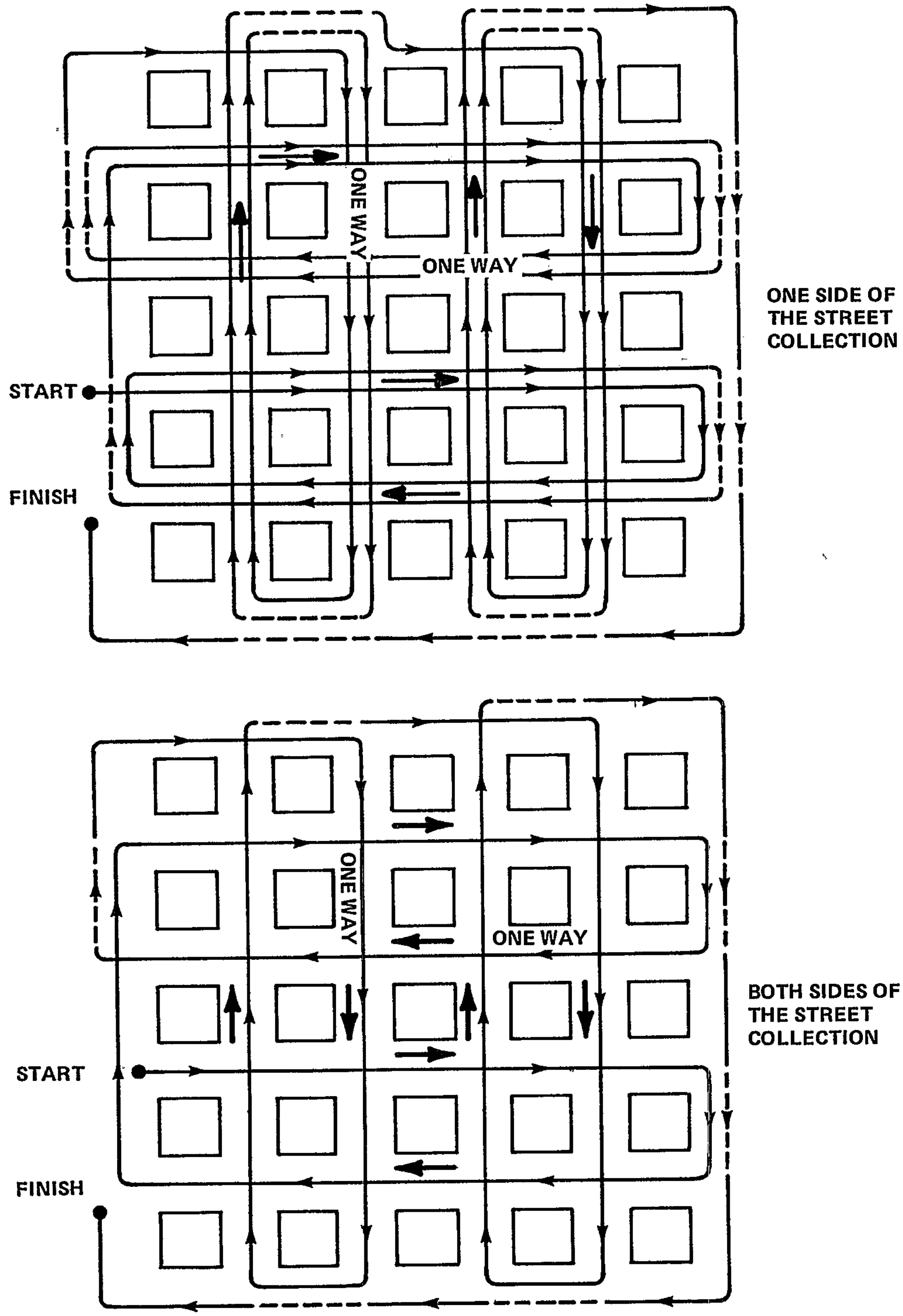
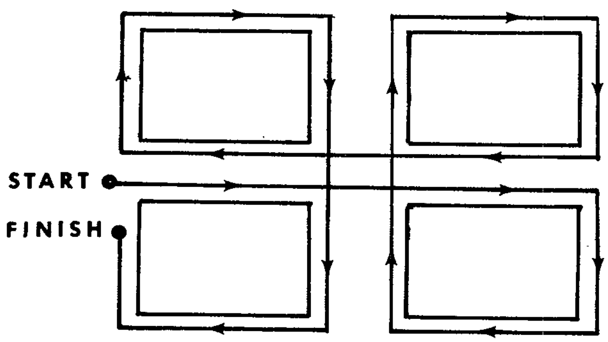


Figure 3. Specific routing pattern for one-way street, one-side-of-the-street collection. In this pattern, collection is made from both sides of the one-way street during the pass. For wide or busy one-way streets, it is necessary to loop back to the upper end and make a straight pass down the other side.

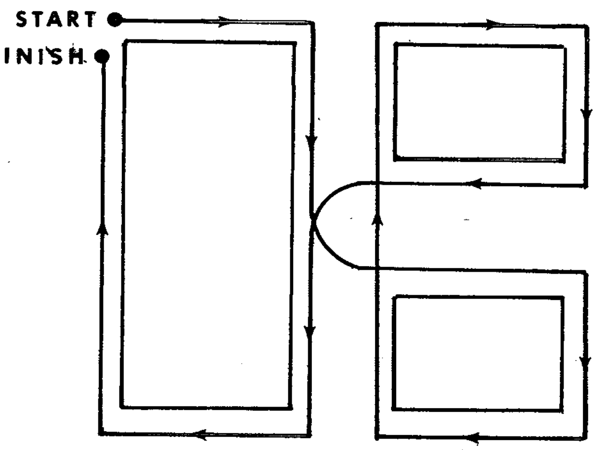


→ DIRECTION OF ONE-WAY STREETS

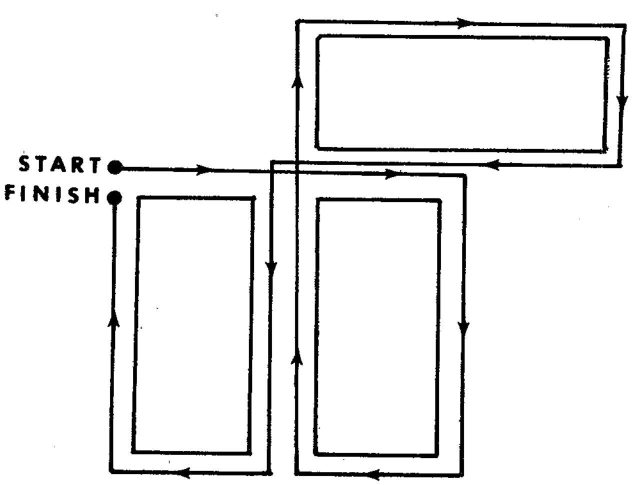
Figure 4. Specific routing patterns for multiple one-way streets. Note the one-way streets are paired with a clockwise movement.



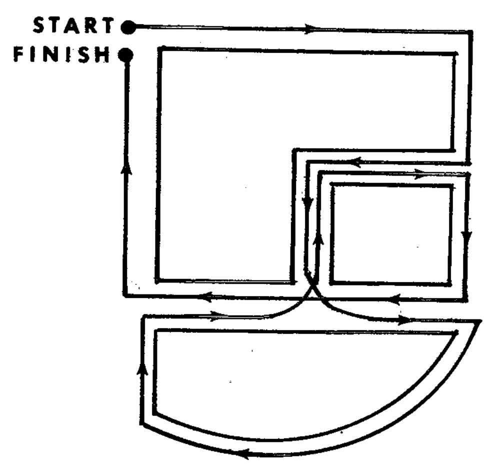
FOUR-BLOCK CONFIGURATION APPLICABLE WHEREVER FOUR BLOCKS ARE POSITIONED AS SHOWN



THREE-BLOCK CONFIGURATION



VARIATION OF THREE-BLOCK CONFIGURATION



VARIATION OF THREE-BLOCK CONFIGURATION

Figure 5. Some specific routing patterns for three- and four-block configurations. In all configurations, blocks may vary in size and shape.

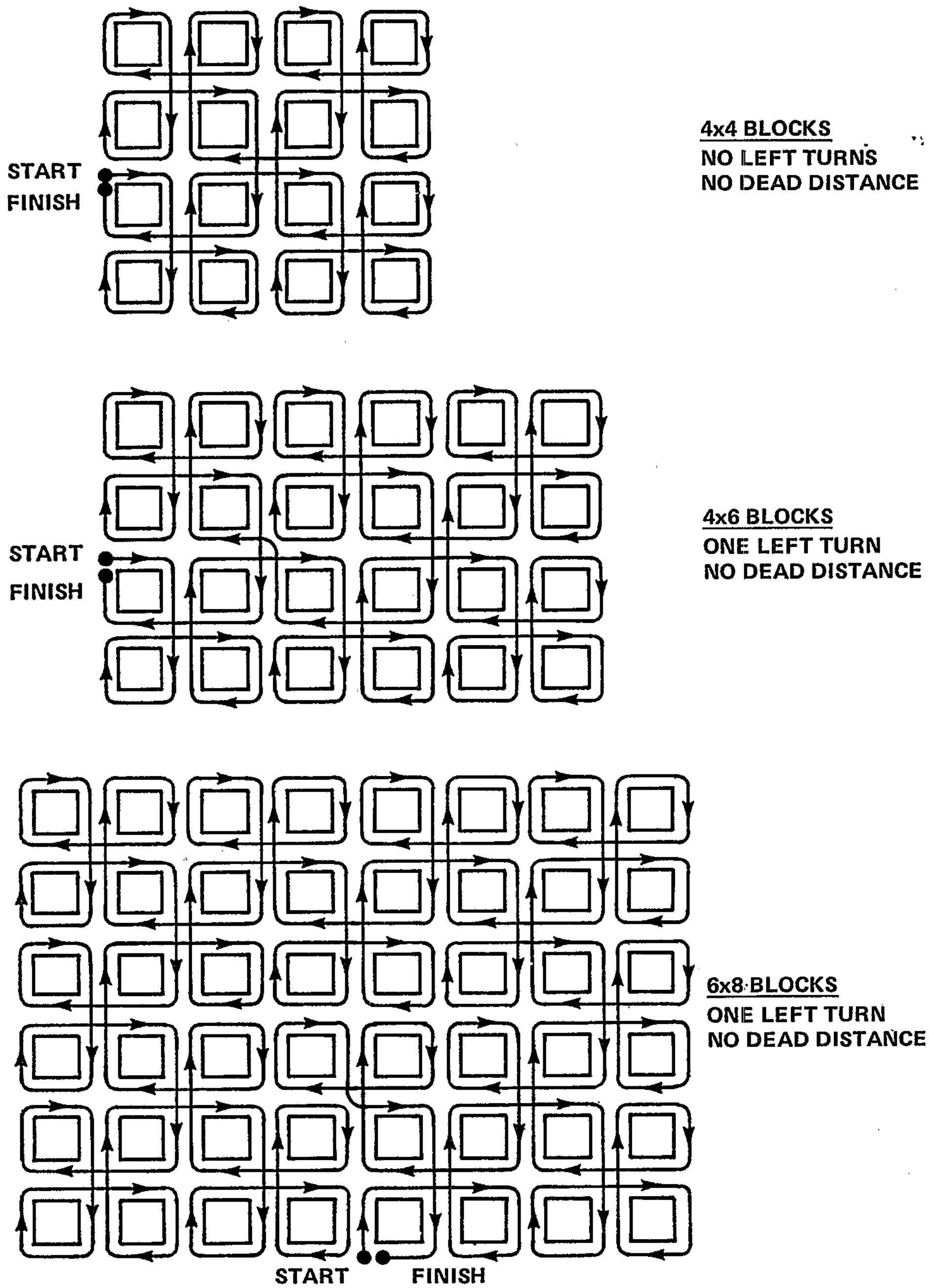


Figure 6. Combinations of the four-block pattern, one-side-of-the-street collection. Note that each route is started midway on an evenly divided side of the grid, and uses the same routing pattern, with progression in a counter-clockwise fashion. For the larger grids, once the outside is routed the inside is routed in a clockwise progression.

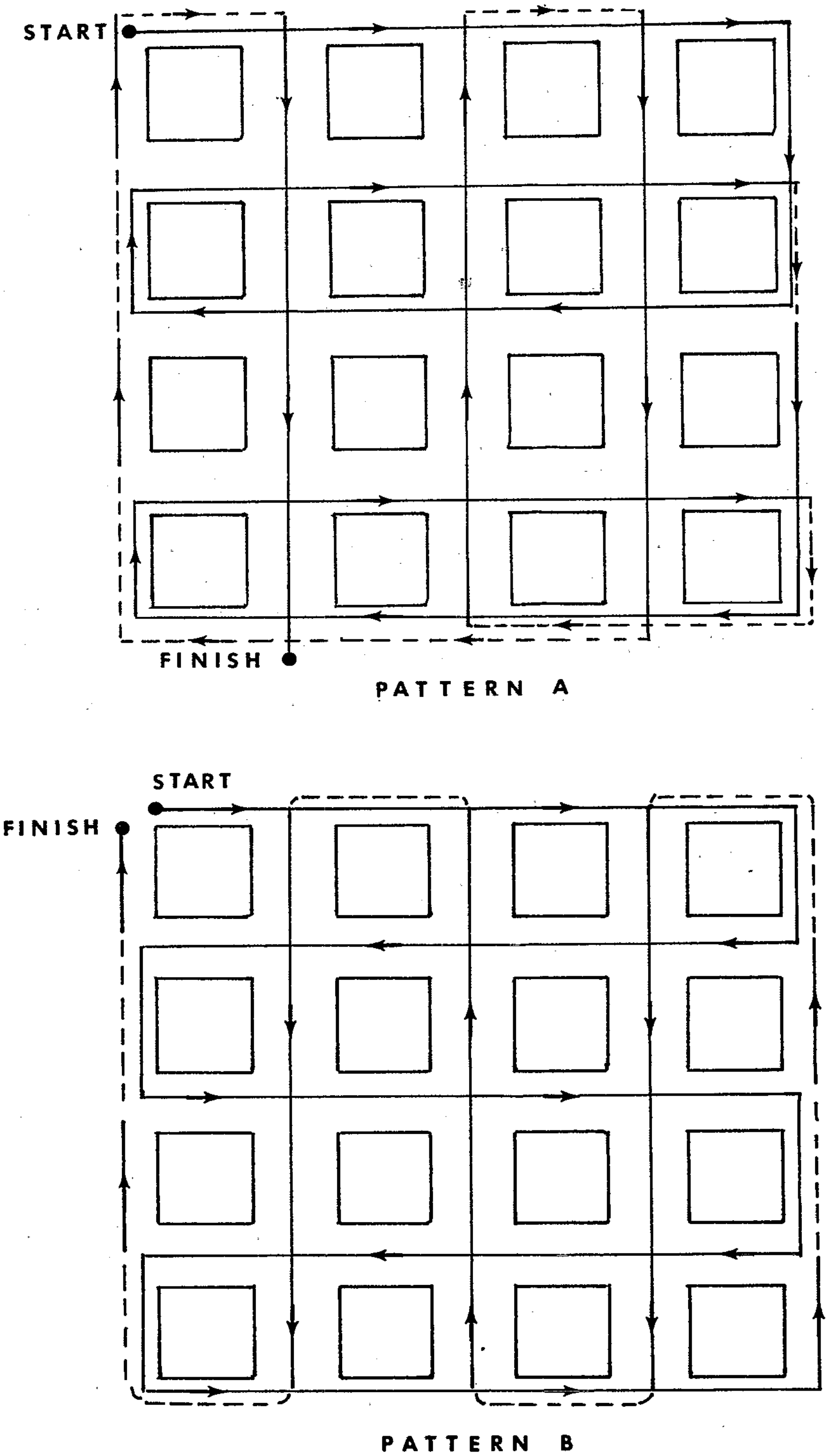


Figure 7. In specific routing patterns for both-sides-of-the-street collection, pattern A entails no left turns, and pattern B requires nine left turns. Dash lines represent "dead distance" or non-collection segments of the route.

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yield efficient route layouts. After determining which street segments have services and which are without services, applying these patterns and developing additional patterns for an efficient route is relatively simple.

To help simplify the problem, a grid simplification technique, described in the section "Routing, How Is It Done?" may be applied before looking for block patterns.

how are the heuristic rules applied?

The heuristic rules are guides which, used in conjunction with the patterns, help determine the vehicle path or route. Because of the infinite possibilities of street and block arrangements and routing patterns, a rigid procedure for routing cannot be applied and thus routing does not lend itself well to being programmed for a computer.

In applying the heuristic rules and patterns, the router should look ahead and behind several street segments and ask himself these questions:

- Do any of the heuristic rules apply here? Are they being violated?
- Have any street segments been left behind that will require a long dead distance to return and pick up?
- Are there already some long dead distances that might be reduced through slight modifications?
- Are there any peculiar or unique characteristics of the area which should be considered?
- Are there any patterns that can be utilized in the routing?

Once the initial layout has been determined, it should be reviewed for further refinements. The route should be retraced and alternate routings or modifications should be attempted wherever long dead distances are apparent. Note, however, that to evaluate *all* possible routing alternatives is a formidable task that even computer models do not attempt.

In summary, the heuristic rules and patterns facilitate the routing process, but must be tempered with a commonsense application and examination as the route is being developed.

PROCEDURES FOR MICRO-ROUTING

what preparations are needed for routing?

In developing an efficient collection system, micro-routing as defined here is actually the last of four tasks that might precede implementation. In order, these tasks are:

- Review and evaluation of existing policies and methodologies
- Macro-routing
- Districting and route balancing
- Micro-routing
- Implementation

A major tool that will assist in all of these tasks is a management information system (MIS) based on a daily collection activity report. The MIS includes route, collection, and cost information records that help identify time and cost centers. A report entitled *Management Information System for Residential Solid Waste Collection* provides further detail.[2]

Collection policies and methodologies directly affect routing and collection efficiency and should be reviewed, evaluated, and changed, if necessary, before rerouting proceeds. This kind of analysis is discussed fully in a report entitled *Policies and Methodologies for Solid Waste Collection.*[3] Policies, which primarily relate to levels of service, include:

- Point of collection (distance from street to storage)
- Frequency of collection
- Type and weight limits of storage device
- Garden waste collection
- Bulky waste (furniture, white goods) collection
- Separate versus combined collection

Methodologies, or on-the-route practices, include:

- Crew size
- Type and capacity of collection vehicles
- Shuttle system
- Reservoir system
- One-side versus two-sides-of-the-street collection
- Fixed lunch site and time
- Collection by drivers
- Incentive schemes
- U-turns and vehicle backing
- Filling vehicles before going to disposal site

After policies and methodologies have been reviewed and revised and the collection areas have been assigned to disposal facilities (macro-routing), districting and route balancing must be performed. The key to districting and route balancing is determining a fair day's work—the reasonable number of services each day for each collection area. Calculating a fair day's work requires at least a sound estimate of the average time spent to service a residence and the amount of waste collected at the residence. These fiqures can be used to derive the average number of residences that can be serviced for each service area, the number of routes required, and the size of each route to equalize workloads. The route balancing process is described more fully in a report entitled *Districting and Route Balancing for Solid Waste Collection.*[4]

Once the equitable service numbers for each route are determined, the community is first divided into districts—one for each collection day in the week. Districts also should conform to manmade and natural barriers such as major streets, railroads, expressways, parks, rivers, lakes, gulleys, and mountains. Each district then is divided into routes—one for each collection crew.

Micro-routing is performed after districting and at the same time the balanced routes are developed. For example, once the service area for Monday is defined, the micro-routing procedure is applied in a clustered area until the predetermined number of services is developed into a route. Then the next route is developed starting in the area which is still unrouted. This procedure continues until the whole city is routed. As the routing process continues, however, the originally selected districts may have to be modified to achieve more efficient routings.

what data are required for routing?

All the information required for routing can be recorded on community maps. First, indicate on the community map(s) the number and type (residential, apartment, commercial, institutional, industrial) of services per street segment for each side of the street. The remaining street segments with no services on them are non-collection segments. Next, identify all one-way, dead end, and heavily traveled streets. Indicate which corner-lot residents (if any) should be asked to place their waste on a specific street segment. Finally, indicate, for each street segment or service area, whether the crews are to collect one or both sides of the street on a pass.

routing, how is it done?

To help simplify the routing problem, it is often helpful to reduce the grid by applying a *grid simplification technique* (Figure 8). By this method, the number of blocks in the grid are reduced by combining blocks that have no services on the common street segments which face each other. The pattern and routing procedure can then be applied to this simplified grid. Also, by getting certain corner-lot residents to place their wastes on specific streets, it may be possible to eliminate the need to traverse the adjoining street. By encouraging neighboring residents to place their wastes together, the collection time can be speeded, and just as important, the stop-and-go wear on the vehicle will be reduced thus extending its life.

Using the marked map, pick a starting point and link the street segments in each district into a continuous route by applying the heuristic rules and patterns to systematically minimize the dead distance and left turns. Terminate the route when the number of services is about that determined to be reasonable for a fair day's work.

Determine the starting point for the next route and repeat the routing procedure, again applying the heuristic rules and patterns until all the services within the district have been routed. Continue until all districts have been routed. As with districting, the service boundaries for each route should be determined by considering natural and manmade boundaries.

For areas with significant seasonal fluctuations in waste generation, the most common solutions are to increase the crew sizes, extend the work day (pay overtime), or add a crew to the reservoir area for peak periods. Another alternative is to shorten each route (i.e., lessen the collection task) and add crews. This kind of adjustment can be readily accomplished in two ways: (1) by designing one continuous collection route for each day of the week or area and then assigning crews to distinct sections of the continuous route based on the previously determined number of services per route; or (2) by establishing different routes for each season of the year. The second method is generally the better of the two.

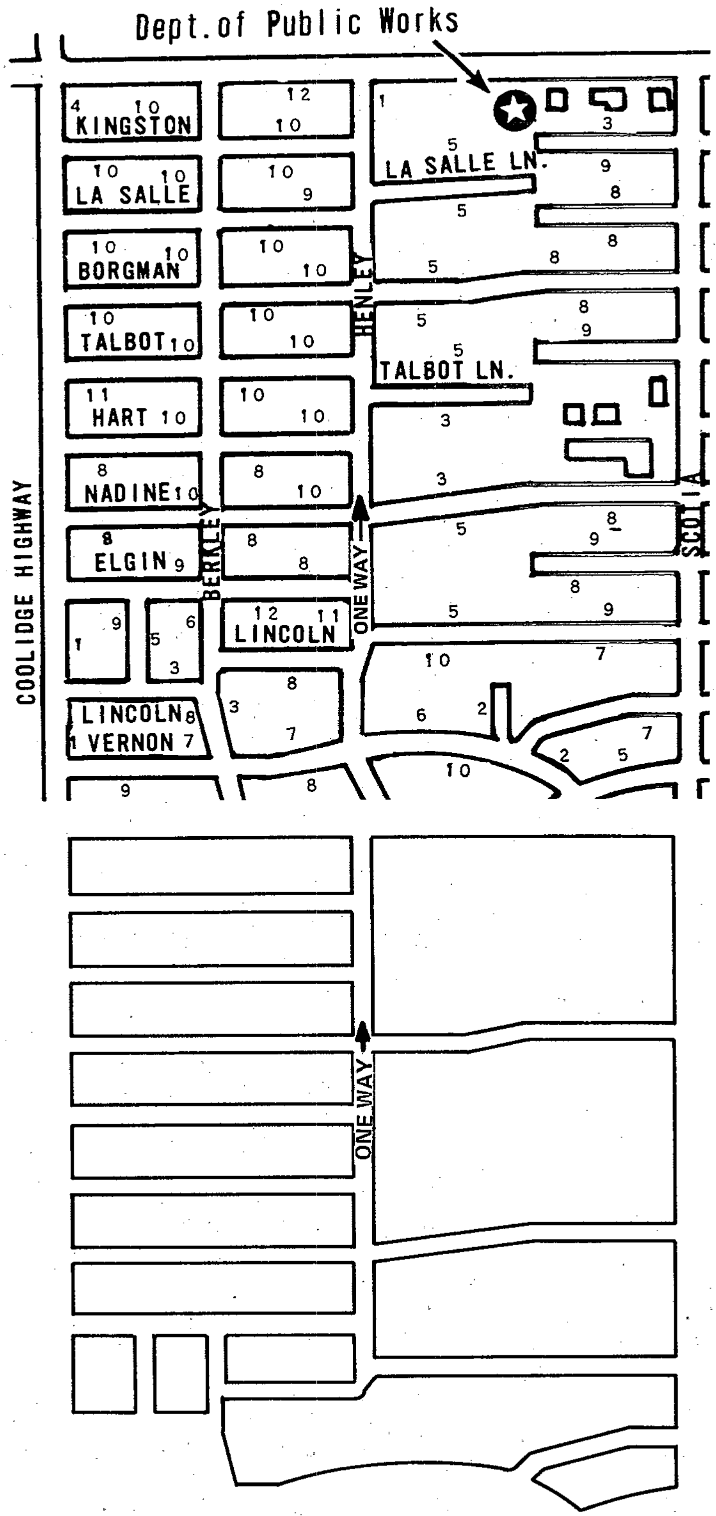


Figure 8. Grid simplification technique. Blocks with no services on common street segments are combined before routing. All of the daily grids in the Huntington Woods example in this report are easily simplified by this technique. This figure shows the Friday route.

PATTERN METHOD OF ROUTING

In the pattern method of routing, the first step is to identify the garage and disposal site locations, heavily traveled streets, one-way streets, and street segments with services (Figures 9 and 10). The garage location is shown on each example, and for simplification, assume no heavily traveled or one-way streets exist and all street segments have services on them.

The next step is to identify block patterns and pick a starting point nearest the garage. In the four- and three-block patterns, the solution is obtained by connecting the patterns together as well as possible through a trial-and-error (heuristic) process (Figure 9).

In the 4 × 4 combination of the four-block configuration, and variations of the three-block configuration, again the solution is obtained through a trial-and-error process of connecting the patterns into a continuous route (Figure 10).

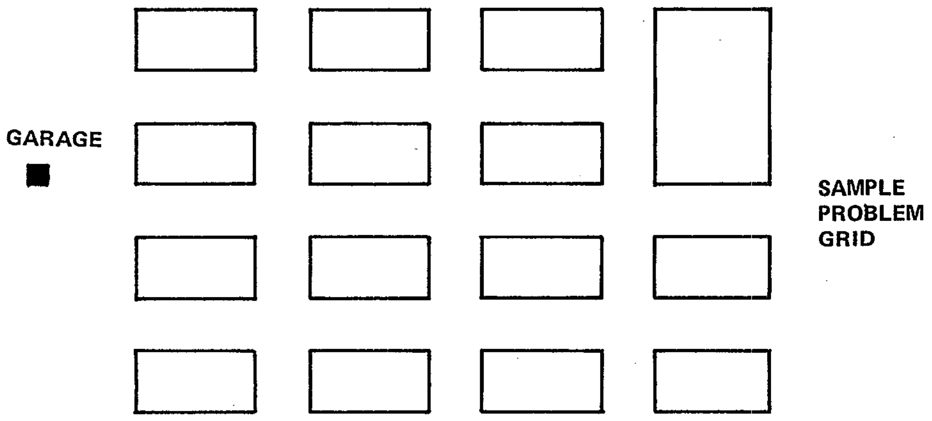
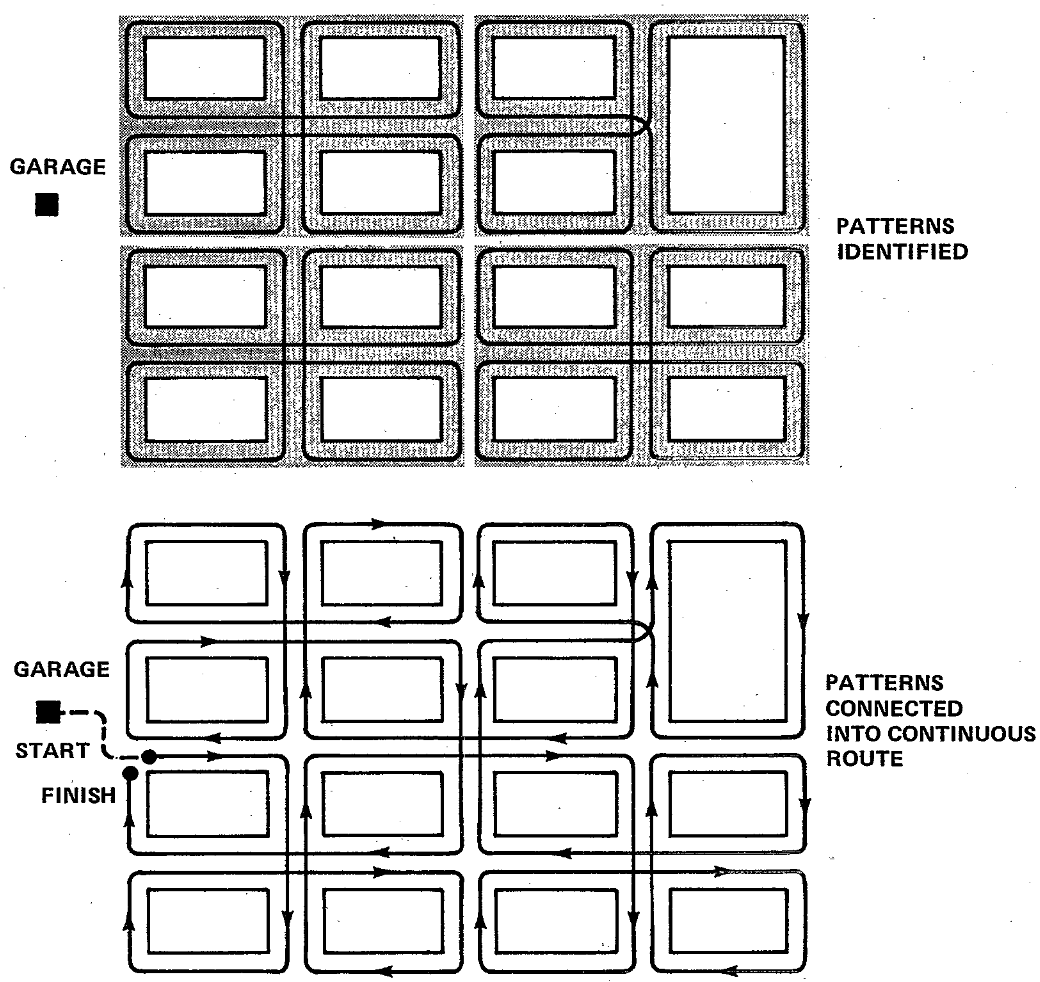


Figure 9. Example showing pattern method of routing. This solution has no dead distance and two left turns.



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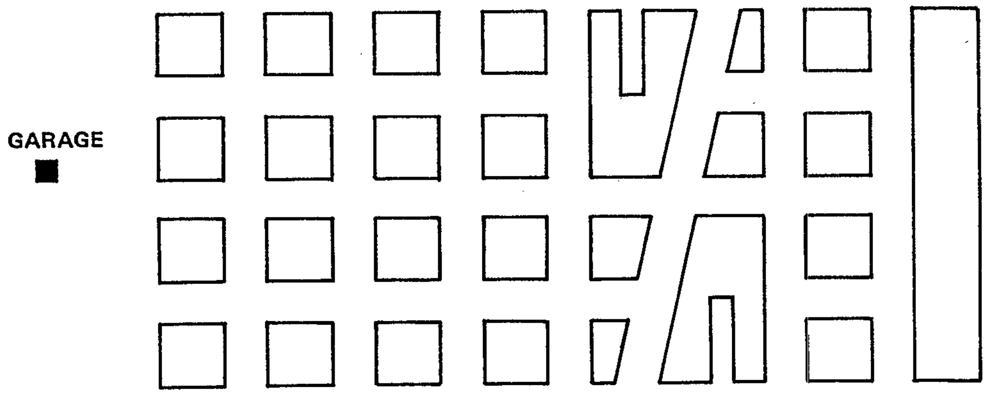
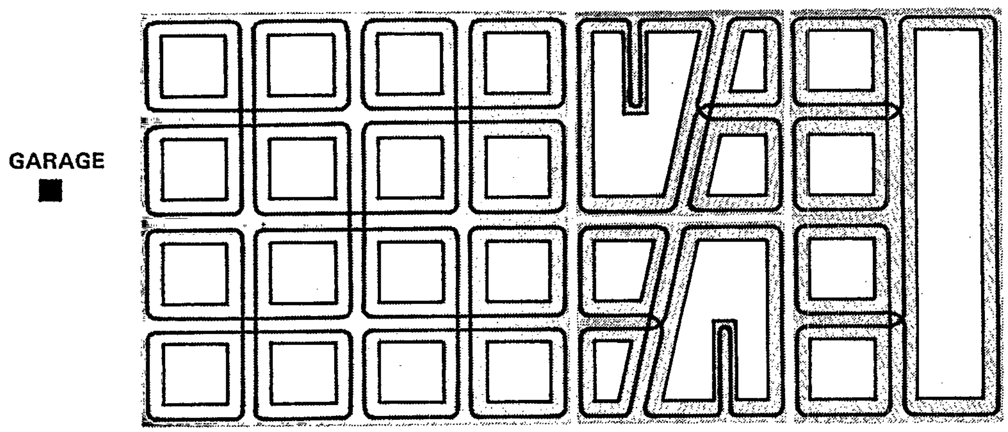


SAMPLE PROBLEM GRID



PATTERNS IDENTIFIED

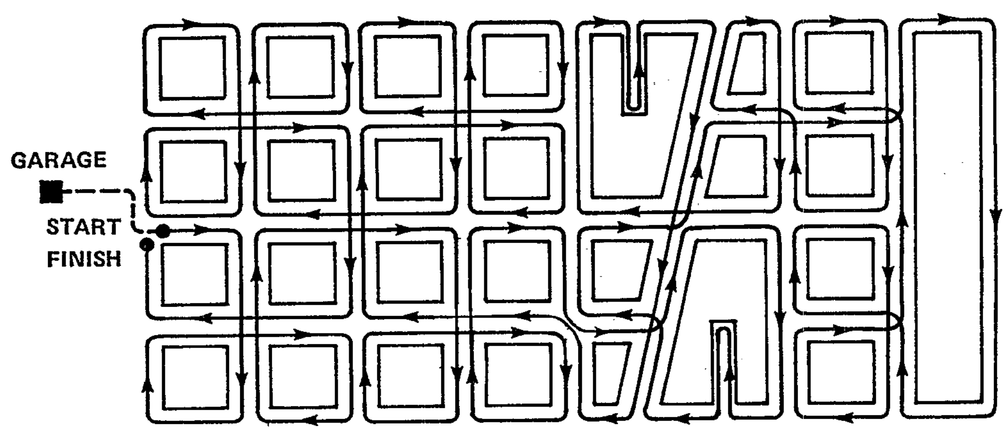


Figure 10. Example showing pattern method of routing. This solution has no dead distance and 10 left turns.

FACTORS TO CONSIDER FOR IMPLEMENTATION

The way in which change is implemented is, of course, as important as the evaluation and design phases that precede it. People generally resist change, even if it is beneficial. A good public education program must, therefore, be developed and tactfully applied to reduce this natural resistance.

As with most alterations in a solid waste collection system, a change in routing affects at least three groups of people: (1) the solid waste management team, (2) the solid waste collectors and drivers, and (3) the public. A public education program should properly inform each of these groups about what is expected of them and enlist their cooperation.

The first group involved in rerouting and other system changes is the solid waste management team. The heuristic approach is designed for the solid waste managers and supervisors to apply. Their participation in the routing serves several purposes. First, it is apt to make them feel that the new system is their system and thus obtain their inherent support. Second, members of the solid waste management team are generally the persons, who, besides the collectors themselves, are most familiar with the service areas and are thus best qualified to perform the routings. And third, management, including supervisors or foremen, must be familiar with the new routings and other changes for supervisory, planning, and control purposes.

The solid waste collectors and drivers should be informed of all proposed changes to the collection system and encouraged to comment on the effect of the changes on their daily operations. Their criticisms or suggestions for further improvement are essential to the final evaluation by the management staff. In addition to being a potential source of pertinent input, the workers' participation in reviewing the decisions may be a useful managerial tool in that it helps them feel a part of the new system.

Several mechanisms can elicit cooperation from the collection personnel and ameliorate employee morale during and after implementation. Unless wages are already rather high, an increase may be considered in light of the increase in productivity (increased services per hour). Or the increased productivity may be rewarded by a new incentive system ,e.g., the task system versus the straight 8-hour day.

To orient drivers to the new routings, each should be given a personal notebook containing a map of each daily route which he may review and use during collection. Examples of the maps are shown for the City of Huntington Woods in the next section. The supervisor should retain a file copy of the route notebook.

Increased efficiency, almost by definition, means that fewer collectors will be required. It also means that more services will be collected per hour. These two factors, plus an understanding of the local labor relations situation, must be considered in determining when to notify collectors of a proposed change in their system, in presenting the change positively, and in deciding if the collectors will assist in rerouting. Often, however, increased productivity can be achieved with a reduced labor force but, at the same time, a reduced workload for the remaining collectors.

Citizens are directly affected by changes in the day and time of collection, the point of collection, the frequency of collection, or the type of storage device. In designing a new system, it is usually a good idea to minimize the number of citizens who will have to change their day of collection, as demonstrated in the Huntington Woods rerouting example. These citizens must be notified of their new collection day and lot residents should also be notified if they are the date the change will take place. All affected corner-lot residents should also be notified if

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they are to place their waste on certain streets.

All citizens in the community—even those whose collection day will not change—should be informed that the solid waste collection service is being altered. Residents often become accustomed to collection at a specific time of day and may set their waste out accordingly, or frequently they relate their own time of collection with that of their neighbors across the street or around the corner, which may have changed. Thus informing everyone should minimize missed collections.

City officials also should be apprised of the proposed changes. Persuaded of these changes, they often are important allies during the transition. Too, should they be approached by citizens regarding the changes, they should be aware of what is taking place.

The most extensive education effort will be directed toward the citizens. Several media are available. One of the best is a letter from the mayor or city manager explaining the reasons for the changes and how the changes may affect the citizens. Such a letter uses a soft-sell approach, implies endorsement by the city management for the new system, and may include a telephone number to call for further information (Figure 11).

Another good way to notify the citizens is through flyers (Figure 12). The letter and flyers shown here are similar to those used in Kansas City, Missouri, during their effective implementation program for a change that took place in March 1971. Note that the flyer is simple, yet it gives all pertinent information. The map helps residents conceptualize the collection area and acts as a check to assure that the flyer was delivered in the correct area. In Kansas City, the actual cards were color-coded by day of the week to assist in answering phone inquiries from the citizens.

Other methods that can effectively inform the public include television and radio announcements and articles and notices printed in local newspapers. Even with an initial multifaceted information program, complete citizen understanding and cooperation requires time and patience. Interpersonal contact may be beneficial: e.g., (1) extra office personnel and perhaps extra telephone extensions to receive complaints and questions during the changeover; or (2) personal interviews with specific corner-lot residents. Finally, using savings as they accrue from the new collection operations to upgrade the cleanliness and appearance of the trucks, replace unreliable trucks, provide uniforms for the collectors, or improve the disposal situation certainly helps sustain good public acceptance.

The next section is a step-by-step account of how the heuristic routing procedure was performed in one of many communities that have recently adopted this approach.

Office of the Mayor

Julius C. Jones, Mayor

City of Anytown, USA
Heart of America

30th Floor, City Hall
Anytown, USA 64106

February 12, 1973

Councilmen at Large

Joseph Hall
1st District

James Smith
2nd District

William Glenn
3rd District

Thomas Rose
4th District

Mark Jones
5th District

Paul Hogan
6th District

District Councilmen

Robert Phillips
1st District

Charles Connolly
2nd District

Alan Michaels
3rd District

Peter Robbins
4th District

William White
5th District

James Myers
6th District

Dear Citizen:

On Monday, March 5, 1973, we will introduce a new City-wide refuse collection system designed to decrease the City refuse budget while still providing the same level of service to you, the citizens.

This savings is made possible through the thorough evaluation of our refuse collection system using the latest of management tools and implementing improved collection techniques.

The collection service will continue to be once-a-week curbside collection. We have, however, revised the City ordinance to permit the use of plastic sacks, which we encourage you to use. Enclosed is a brochure explaining the advantages to you and to the City through the use of plastic sacks, and some helpful hints on bag usage and refuse storage.

The only change affecting the citizens directly is a change for some in their day of collection. We have tried to minimize the number of citizens that must change their day of collection. This new collection system means, however, that in most instances the time of day that the collectors collect from each residence will change. The enclosed map shows the day of collection for each area. Please note when your new day of collection will be starting March 5.

Please help our sanitation men provide service to you during this change-over by having your waste put out by 7:00 a.m., the time they start to collect.

If you have any questions or suggestions, please call 684-4311.

Thank you for your cooperation in this effort.

Sincerely,

Julius C. Jones

Julius C. Jones
Mayor

Figure 11. Sample letter from a mayor to citizens notifying them of a change in collection system.

Important Notice

Beginning March 5, 1973
Your New Refuse Collection Day will be

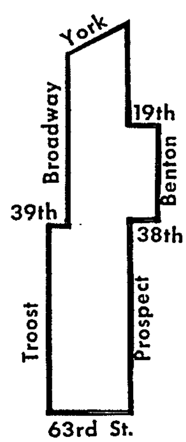
tuesday

There will be no collection on the following holidays:

May 28, 1973	*October 22, 1973*
September 3, 1973	*December 25, 1973*
October 8, 1973	*February 18, 1974*

If a holiday is observed on Monday or Tuesday, your collection day for that week will be WEDNESDAY.

For information call 254-7417



Public Works Department
Refuse Division
Anytown, U.S.A.

Important Notice

Beginning March 5, 1973
Your New Refuse Collection Day will be

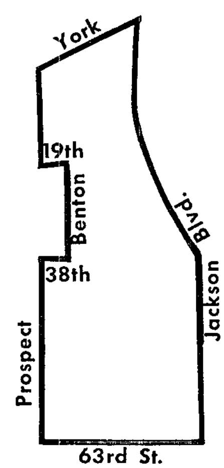
wednesday

There will be no collection on the following holidays:

May 28, 1973	*October 22, 1973*
July 4, 1973	*December 25, 1973*
September 3, 1973	*February 18, 1974*
October 8, 1973	

If a holiday is observed on Monday, Tuesday, or Wednesday, your collection day for that week will be THURSDAY.

For information call 254-7417



Public Works Department
Refuse Division
Anytown, U.S.A.

Figure 12. Flyers are effective media for informing citizens of changes in collection system.

APPLYING HEURISTIC ROUTING TO HUNTINGTON WOODS

The Office of Solid Waste Management Programs assisted the City of Huntington Woods, Michigan, in applying a heuristic approach to rerouting its solid waste collection vehicles. This section briefly characterizes the community's existing collection system at the time study was initiated and its new collection system, and traces the development of its new collection routes.

Huntington Woods is a middle-class suburban community just outside Detroit. The population (1970 census) is 8,536, which represents 2,497 residences. From solid waste disposal records the average solid waste generation rate was estimated to be about 1.3 kg (2.9 lb) per capita per calendar day, or an average of about 31.5 kg (70 lb) of solid waste each week from each residence. Seasonal variations in the amount of solid waste, which must be considered in designing an efficient collection route, were also determined before the rerouting study.

evaluating existing policies

A thorough review and evaluation of the city's existing solid waste collection policies provides the basis for a "before and after" comparison that reflects the increased efficiency of collection system operations. Under both the former and the new systems, the city provides weekly curbside collection service to all residents and to the city's few commercial services. About 80 percent of the city's residents use plastic bags for waste storage. The city's collection system formerly used two 12.2-cu meter (16-cu-yd), rear-loading packer trucks operated by two two-man crews to collect one side of the street at a time.

The Huntington Woods city management personnel considered a rerouting program necessary because they had acquired new collection equipment. The city had purchased a one-man, side-loading collection vehicle to replace one of the older rear-loading packer trucks. During a trial period, the replacement was able to finish the collection routes in approximately 5 hours. Thus, although the city had saved the equivalent of 1 man-year in labor costs, the potential for even greater savings through rerouting appeared very promising.

compiling the data

The data required for rerouting the City of Huntington Woods included a series of three maps. The first, prepared by the superintendent of the Department of Public Works, was a detailed street map of the city showing the number of residential services for each street segment (Figure 13). Note that it is important to correctly identify the number of services on each side of a particular street segment and the location of the Department of Public Works garage or motor pool. A separate city map was prepared to identify all one-way, heavily traveled, and dead end streets (Figure 14).

A third map identified those street segments where no waste would be placed for collection, i.e., undeveloped segments with no services and corner-lot residences that do not face the street (Figure 15). By correctly designating these segments, they can be eliminated from the design of the collection route and thus help minimize the dead distance in the individual routes. In Huntington Woods, many such street segments were identified by asking residents of corner lots to place their waste on a specific street segment (though in most cases the corner-lot houses faced the desired street segment and the waste was already being placed there).

Figure 16 shows the former collection routes before rerouting and a breakdown of service areas by day of the week. A comparison of each truck's daily workload shows definite imbalances between the two trucks and in the general workload from day to day, even though service density and the amount of waste per service are similar for each route (Table 2). On Monday, for example, Truck No. 1 serviced 281 residences and Truck No. 2 serviced 305 residences, a total of 586 services. On Friday, however, these same trucks collected 131 and 183 residences, respectively, a total of only 314 services. The old collection routes were fragmented; the Wednesday and Thursday collection routes, for example, are typical of both fragmented and unbalanced routes that most likely evolved with the development of the community (Figure 16).

reviewing existing and alternative operations

At this point in the rerouting study the city reviewed its existing collection system operations and identified possible alternatives. The city management isolated four major areas of the collection operation where possible alternatives existed. The areas, along with the alternatives, were:

1. *Equipment*
   Side-loader, 22-cu-meter (29-cu-yd), (one available)
   Rear-loader, 12.2-cu-meter (16-cu-yd), (two available)
2. *Crew size*
   One-man, side-loader only
   Two-man, driver and one collector
   Three-man, driver and two collectors
3. *Level of service*
   Curbside, once a week
   Carryout, once a week (requires additional personnel)

TABLE 1

SEASONAL VARIATIONS IN SOLID WASTE COLLECTION
CITY OF HUNTINGTON WOODS, MICHIGAN

Season	Solid waste to be collected			
	Average wt/day		Average wt/ residence/wk	
	tonnes	tons	kg	lb
Winter	10.6	11.8	21.2	47.2
Spring	15.0	16.7	30.1	66.8
Summer	18.2	20.2	36.4	80.8
Fall	19.2	21.3	38.3	85.2

TABLE 2

RESIDENCES SERVICED BY DAY OF WEEK AND TRUCK

Vehicle	Residences serviced					
	Mon.	Tues.	Wed.	Thur.	Fri.	Daily Average
Truck No. 1	281	289	220	323	131	248.8
Truck No. 2	305	267	328	170	183	250.6
TOTAL	586	556	548	493	314	499.4

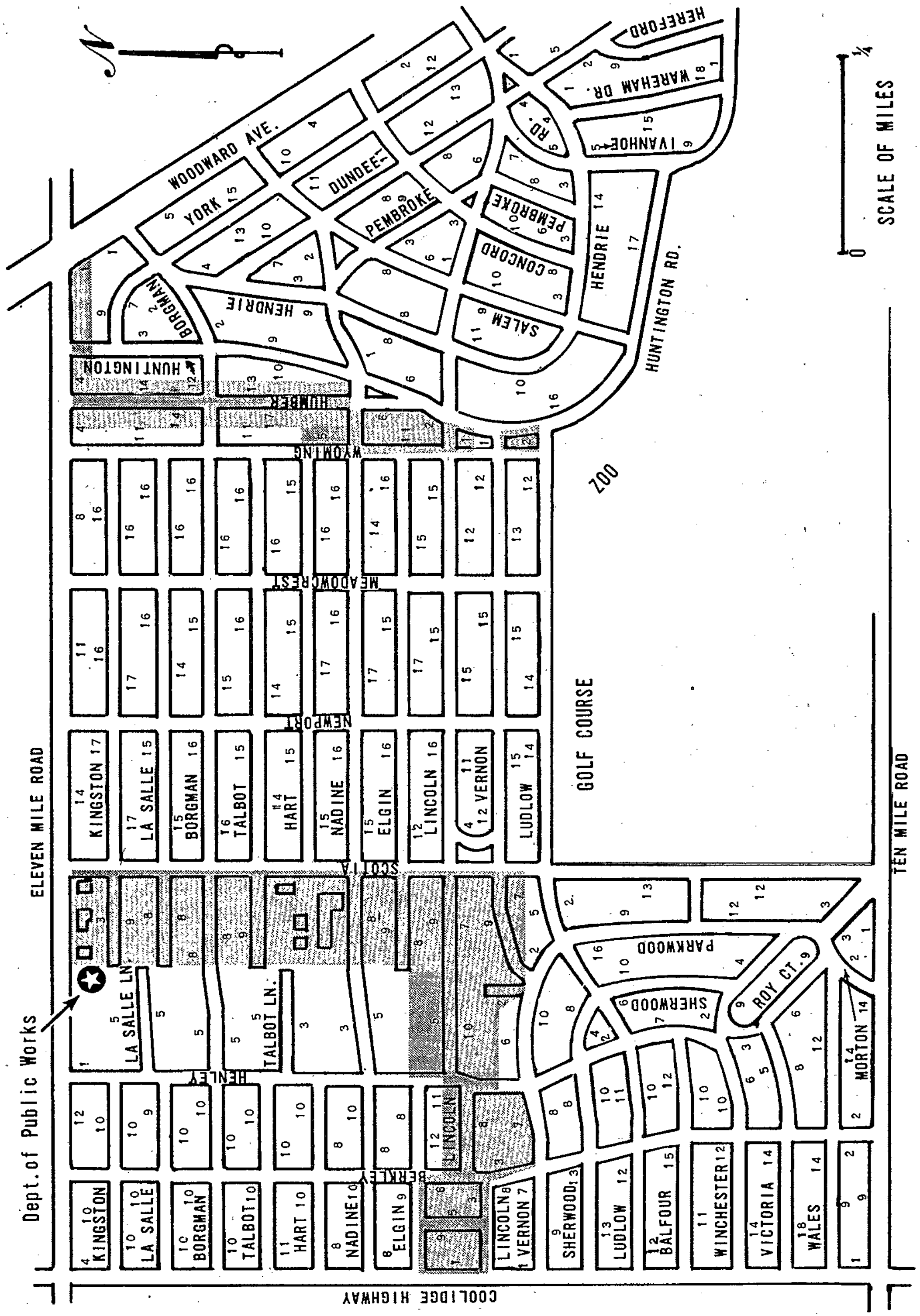


Figure 13. Detailed community map of Huntington Woods, Mich., showing services per street segment.

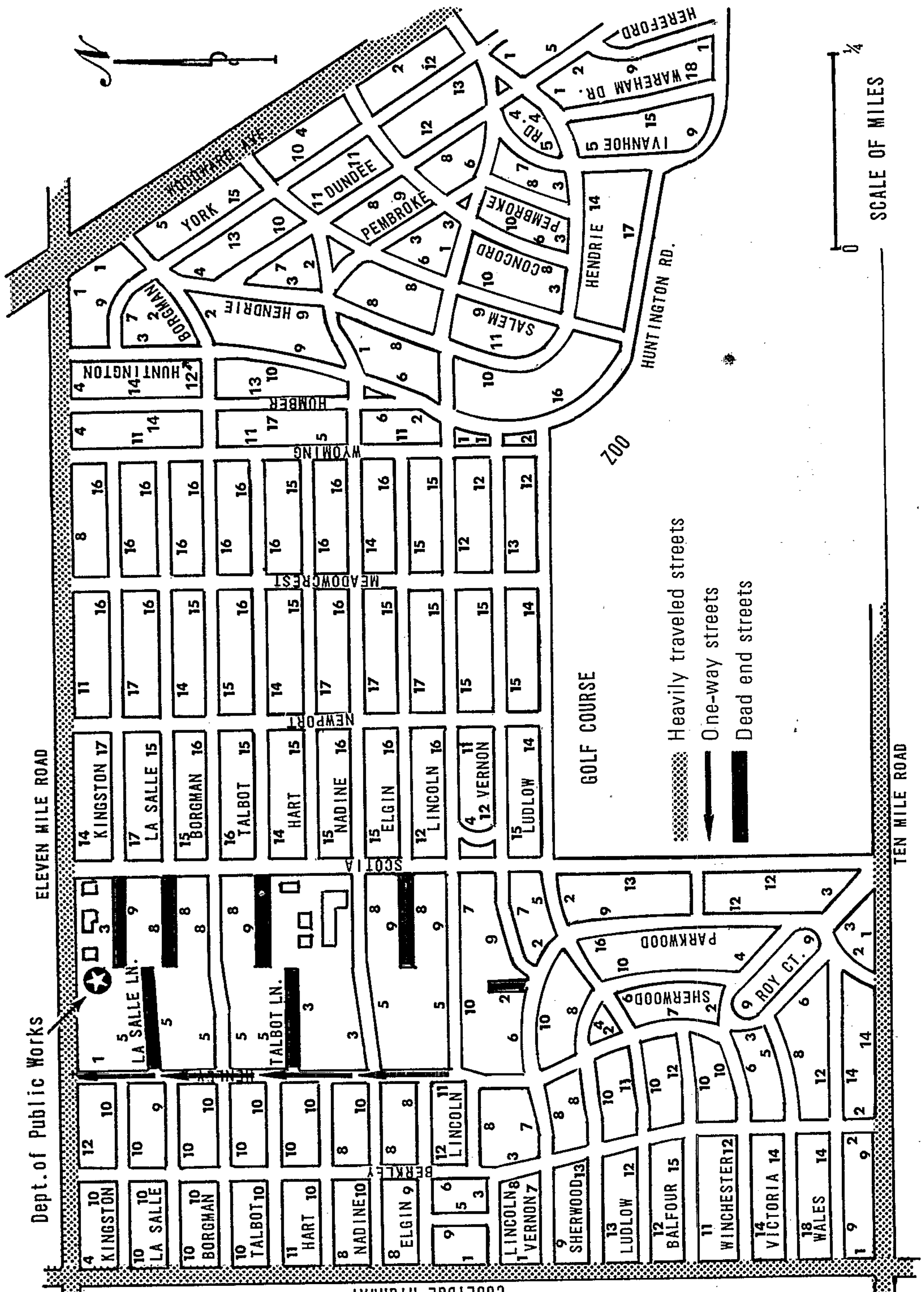


Figure 14. Detailed community map showing special streets.

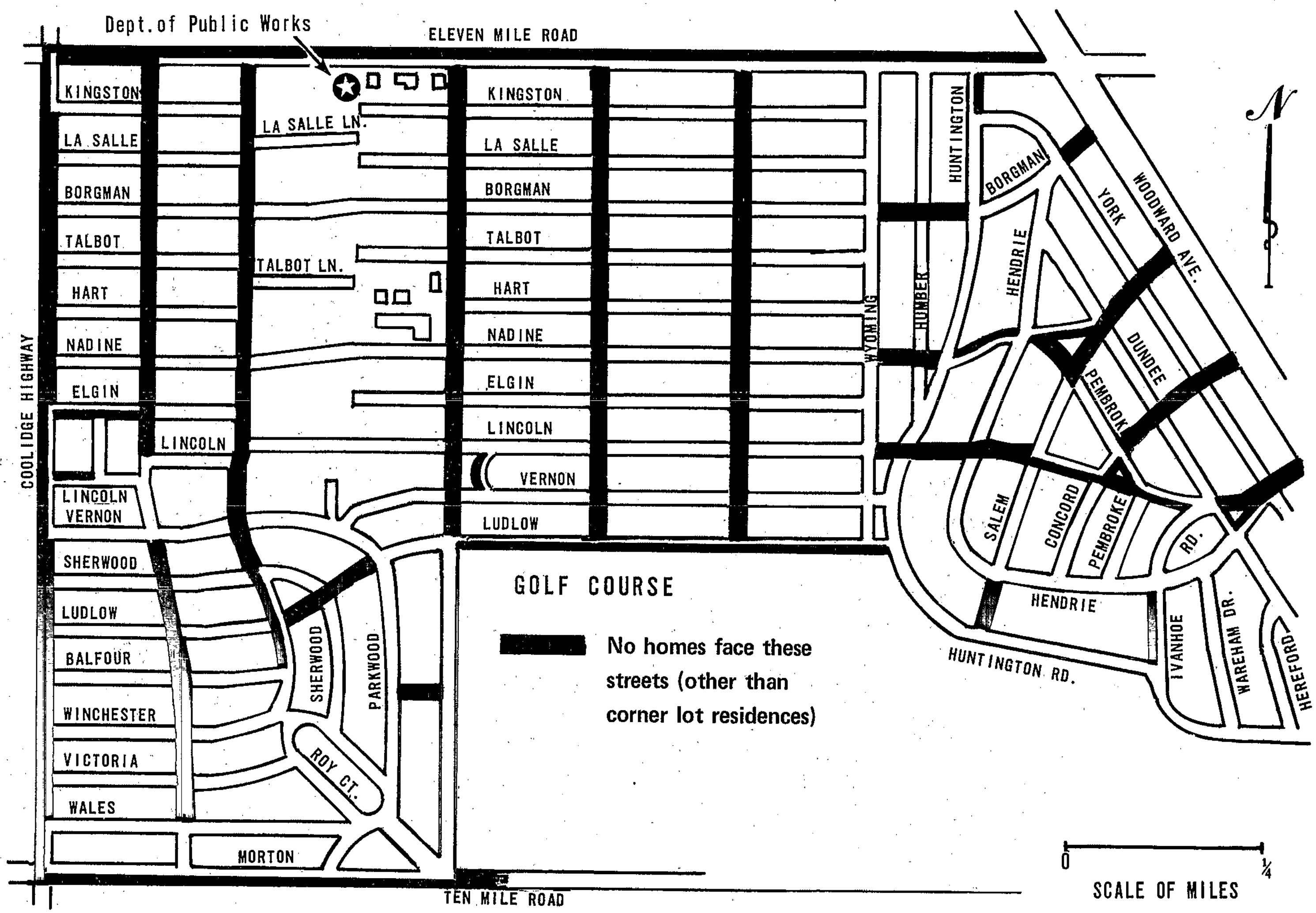


Figure 15. Detailed community map showing non-collection street segments.

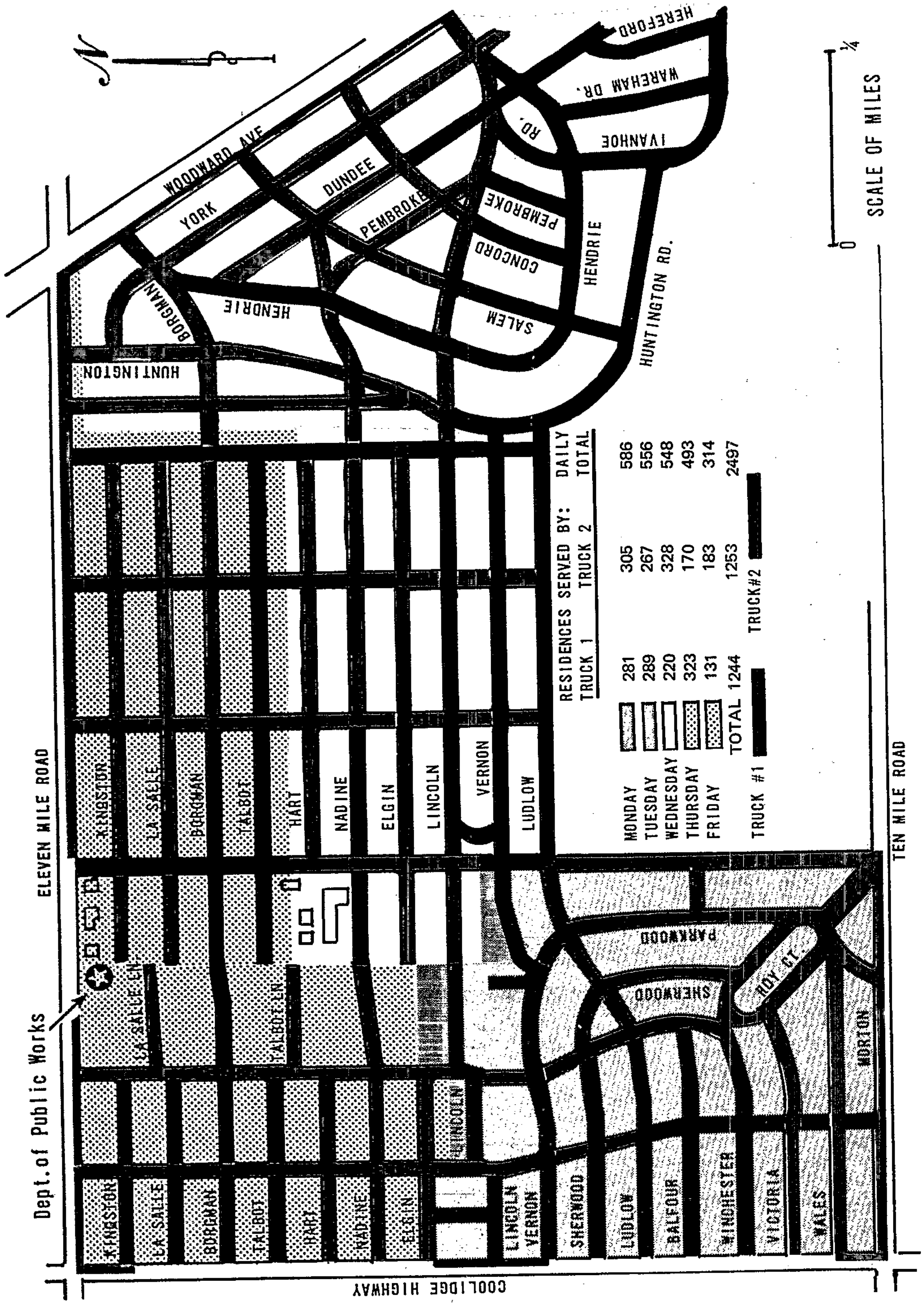


Figure 16. Former collection routes.

4. *Collection methodology*
   Collection from one side of street
   Collection from both sides of street
   Plastic bags as mandatory storage containers

The city management felt that the existing level of service (curbside, once a week) and collection policy (collecting from one side of the street and voluntary use of plastic bags) was the best of the alternatives considered. With respect to equipment and crew size, the city management wished to fully utilize the new one-man collection vehicle and collect any remaining waste using a rear-loading packer truck with a two-man crew. Thus the collection system was defined by the city, and all that remained was the design of the collection routes.

Some additional data were required before the actual heuristic routing could be started. The average round trip time to the disposal site, average time per service, average number of services per street mile, and average weight per service are all important parameters in the design of any efficient collection route and can be obtained by using a daily collection activity report. In Huntington Woods, the average round trip time to the disposal site is 45 minutes; the average time per service during peak generation periods is 0.5 minutes and the average weight per service during the peak generation period is 38.2 kg (85 lb) per residence per week.

To determine the total number of collection routes required, the total number of residences (2,500) was divided by 5 (maximum number of possible collection days), which resulted in a daily workload of 500 services. Thus, using an average 0.5 minutes per service, an average of 250 minutes per day, or about 4.25 hours per day, would be required to collect waste from 500 residential services during the peak season. The low collection time of only 0.5 minutes per service is largely due to the use of plastic bags by 80 percent of the residents. One-way bags reduce collection time per service.

Using the peak solid waste generation rate of 38.2 kg (85 lb) per residential service, the total weight collected from 500 services should be about 19.12 tonnes (21.25 tons) per day. The city's one-man collection vehicle has a 22-cu-meter (29-cu-yd) capacity which can handle payloads of up to 7.2 tonnes (8 tons) or 326 kg/cu meter (550 lb/cu yd). Thus during the peak season, with an average of 19.2 tonnes (21.25 tons) of solid waste to be collected and a collection vehicle with an average payload of 7.2 tonnes (8 tons), three trips to the disposal site are required. At the average 45 minutes per trip, the total time required for three trips to the disposal site is 2.25 hours per day.

The city policy allows two 15-minute coffee breaks per day and a 30-minute lunch period. The lunch break is not paid time and can be taken at the convenience of the collector. Times are apportioned for the various activities of the collection operation, based on 500 services per day and the one-man collection vehicle (Table 3). The 1-hour variance allows for day-to-day variations in waste generation, unusual delays at the disposal site, and adverse weather conditions. From the data analysis, the solid waste collection routes for the City of Huntington Woods should be designed to include approximately 500 residential services per route.

determining the new routes

Because the number of services per collection route is the single most important parameter in designing an efficient collection route, at this point in the routing study the extrapolated average number of services should be verified. In Huntington Woods, the existing Wednesday collection routes serviced 548 residences; therefore the two were combined and selected as a test route for the one-man collection vehicle. All 548 residences were adequately serviced in less than the 8-hour work day. Thus the proposed 500 services per route appeared to be a very reasonable workload for the new collection system configuration.

The City of Huntington Woods was rerouted manually using the heuristic approach (Figure 17). A comparison of past and present collection routes dramatically depicts the changes in service areas by day of the week and route assignment (Figures 16 and 17). A comparison of the performance of the former collection system and the new rerouted collection system shows that Truck No. 2, a rear-loading packer truck, has been completely eliminated and that Truck No. 1, the one-man collection vehicle, is servicing the entire city (Table 4). The new collection routes are continuous, balanced, and not fragmented or overlapping.

New street-by-street collection routes were developed for the Monday through Friday service areas (Figures 18 through 22). The previously outlined heuristic rules and patterns, and a systematic approach were the basis for the design of all the collection routes. Note that since the route is continuous, the collector may leave the route for a trip to the disposal site whenever his vehicle is fully loaded and simply return to the point of departure to continue collection.

implementation considerations

Successful implementation of the proposed collection routes depended upon securing the support of the collection personnel and the citizens of the community.

The collection personnel were directly involved in and contributed to the rerouting study by providing much of the required data and by reviewing the proposed changes. The collector was given a complete route book graphically describing the service area for each day of the week and street-by-street routing of his vehicles (Figures 18 through 22). The added responsibility of operating the new one-man collection vehicle and the increased number of services justified a wage raise. Displaced collection personnel were reassigned to other areas of the Department of Public Works.

To balance the service areas into equal workloads, only simple changes in the service area boundaries were required, thus minimizing the areas of the city where the day of collection was changed because of rerouting (Figure 23). Only 275 residences, or about 11 percent of the total residences in the city, were affected by a change in the day of collection. A letter from the office of the city manager informed these residents of the change in collection day and requested their cooperation.

TABLE 3

TIME REQUIRED FOR VARIOUS COLLECTION ACTIVITIES

Activity	Average time required (hr)
Collection	4.25
Disposal	2.25
Coffee break (2)	.50
Variance	1.00
TOTAL	8.00

TABLE 4

RESIDENCES SERVICED: OLD AND NEW COLLECTION ROUTES

Route	Residences serviced				
	Mon.	Tues.	Wed.	Thur.	Fri.
Former collection routes:					
Truck No. 1	281	289	220	323	131
Truck No. 2	305	267	328	170	183
TOTAL	586	556	548	493	314
New collection routes:					
Truck No. 1	500	492	494	517	494
Truck No. 2	0	0	0	0	0
TOTAL	500	492	494	517	494

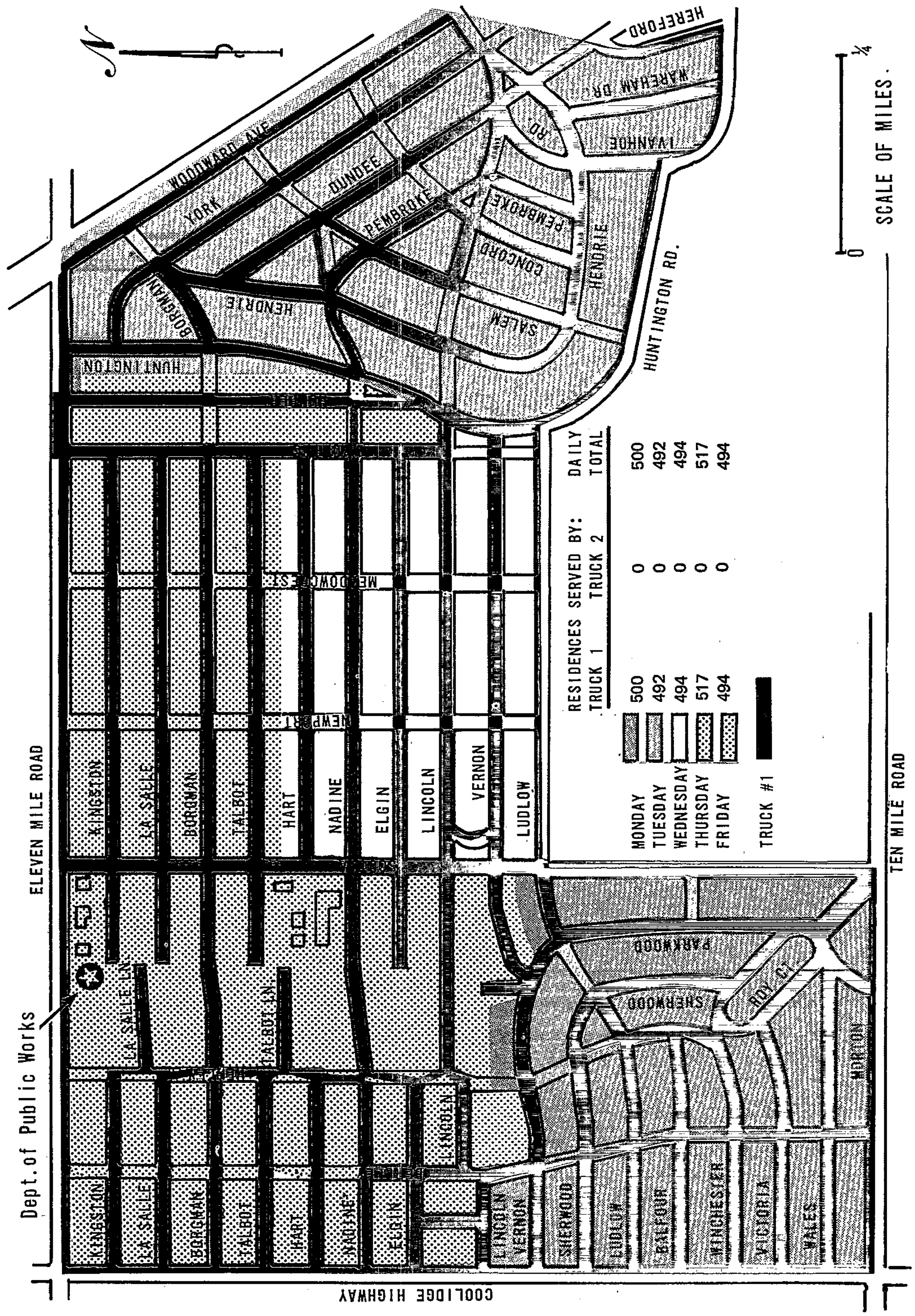


Figure 17. New collection routes.

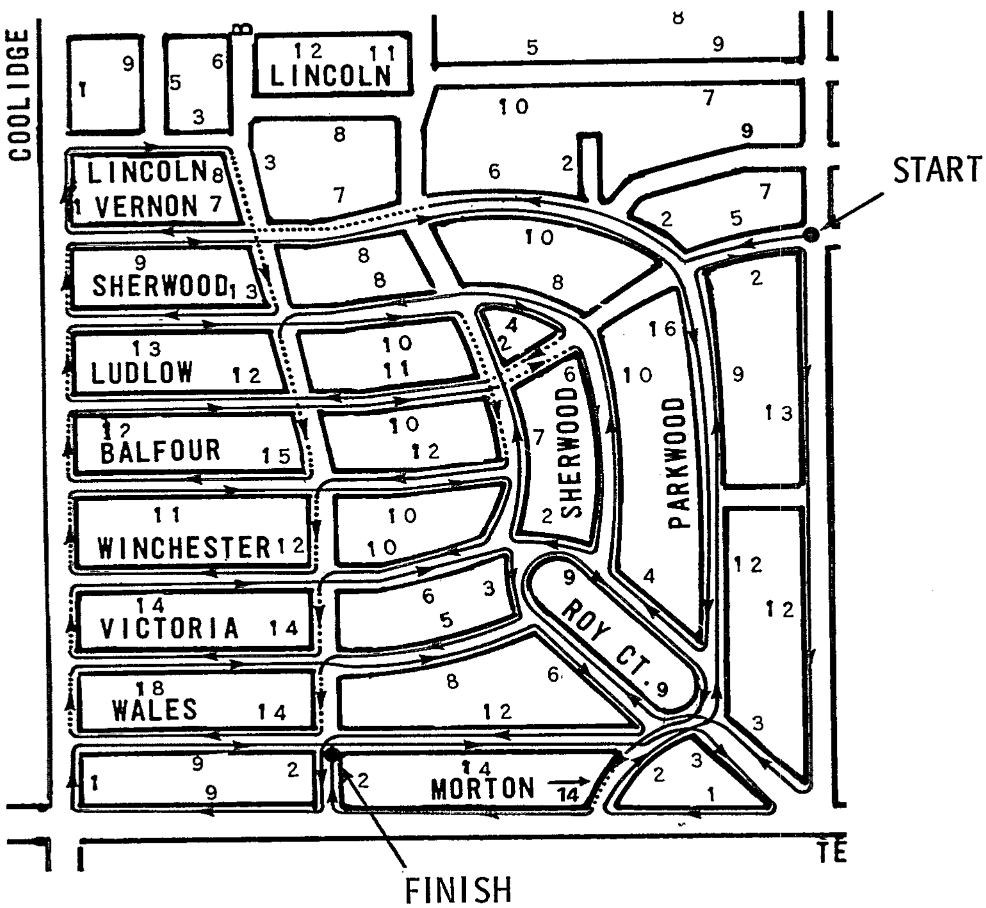


Figure 18. Monday collection route: 500 residences; five left turns.

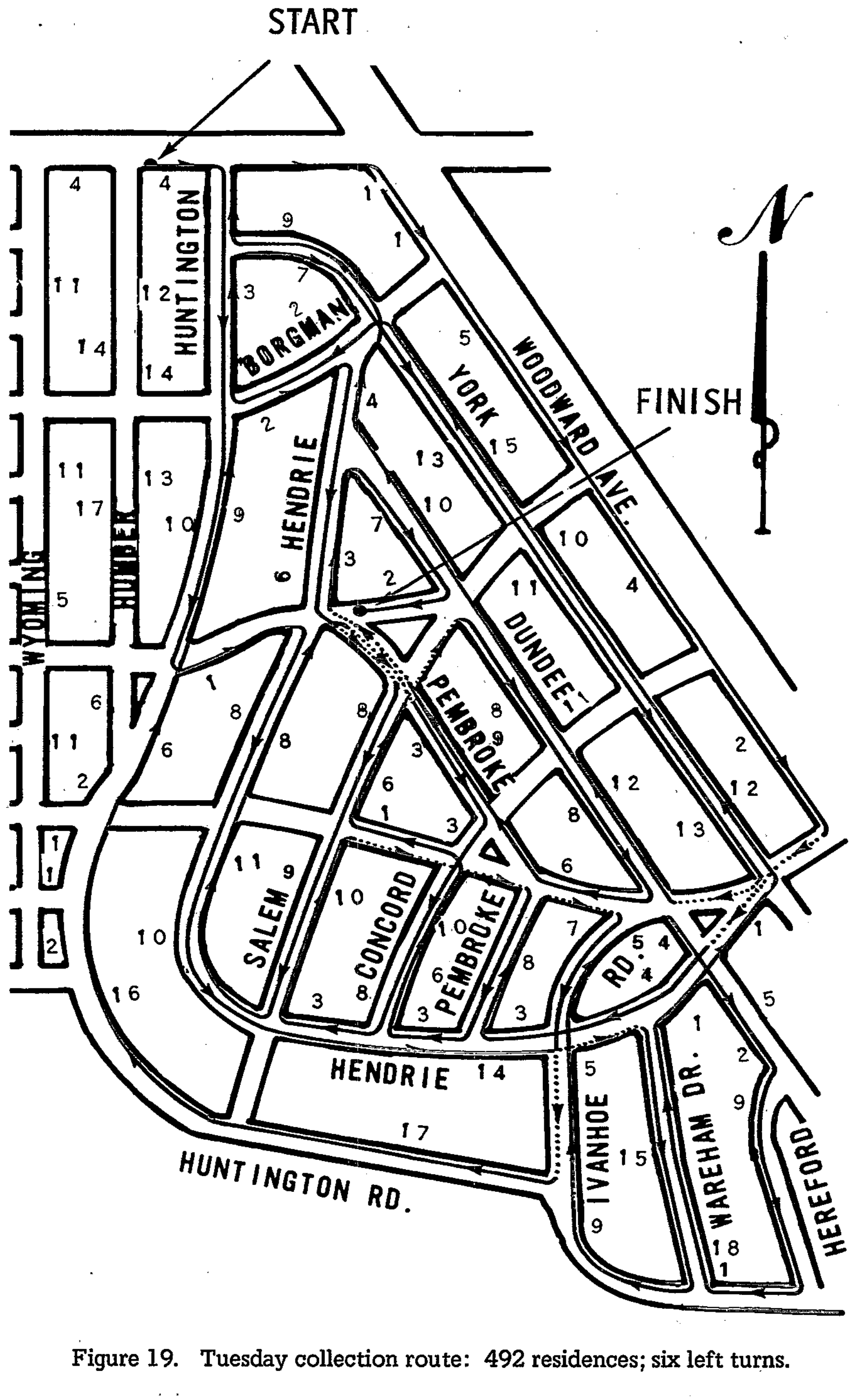


Figure 19. Tuesday collection route: 492 residences; six left turns.

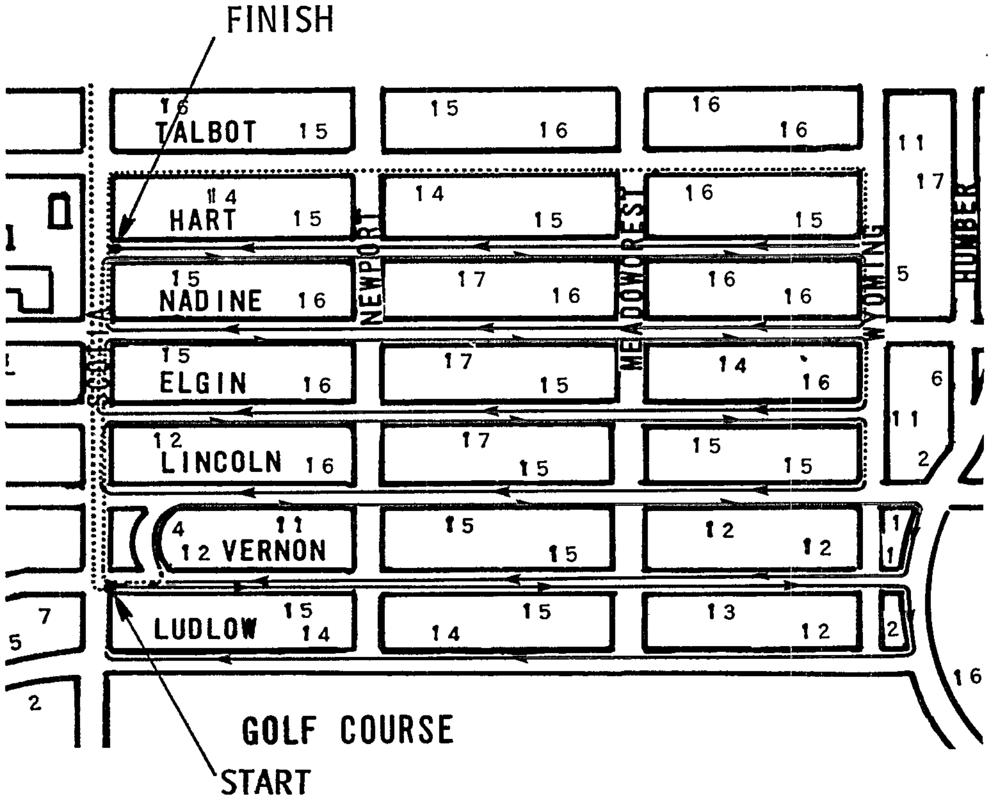


Figure 20. Wednesday collection route: 494 residences; one left turn.

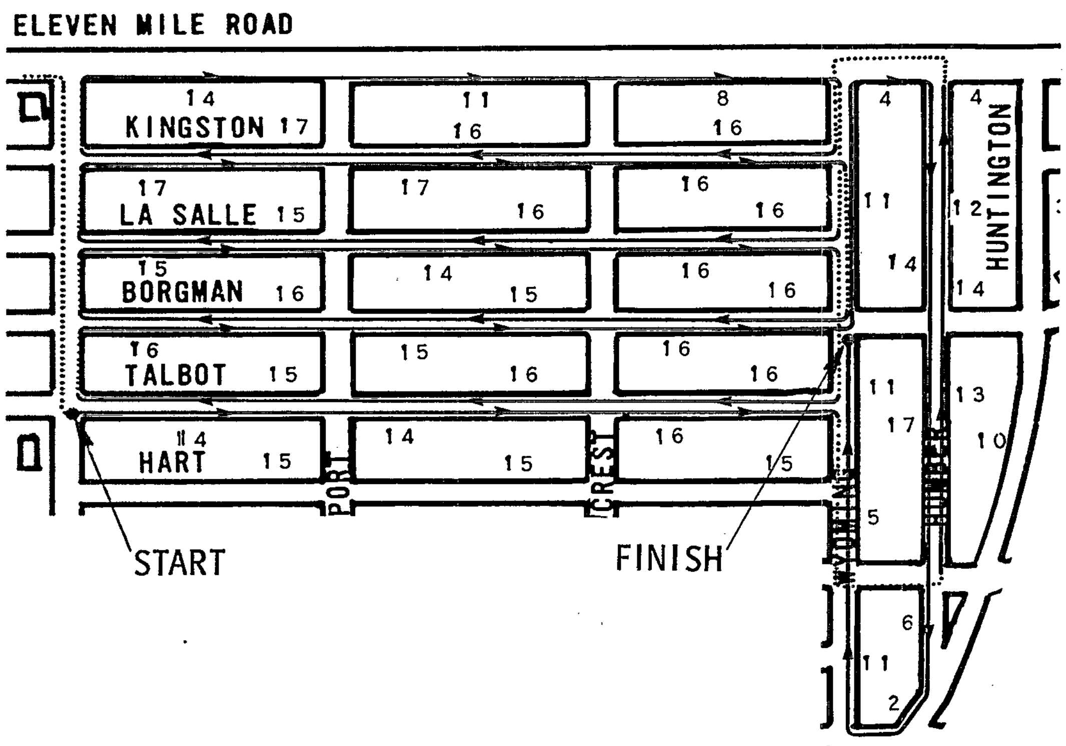


Figure 21. Thursday collection route: 517 residences; five left turns.

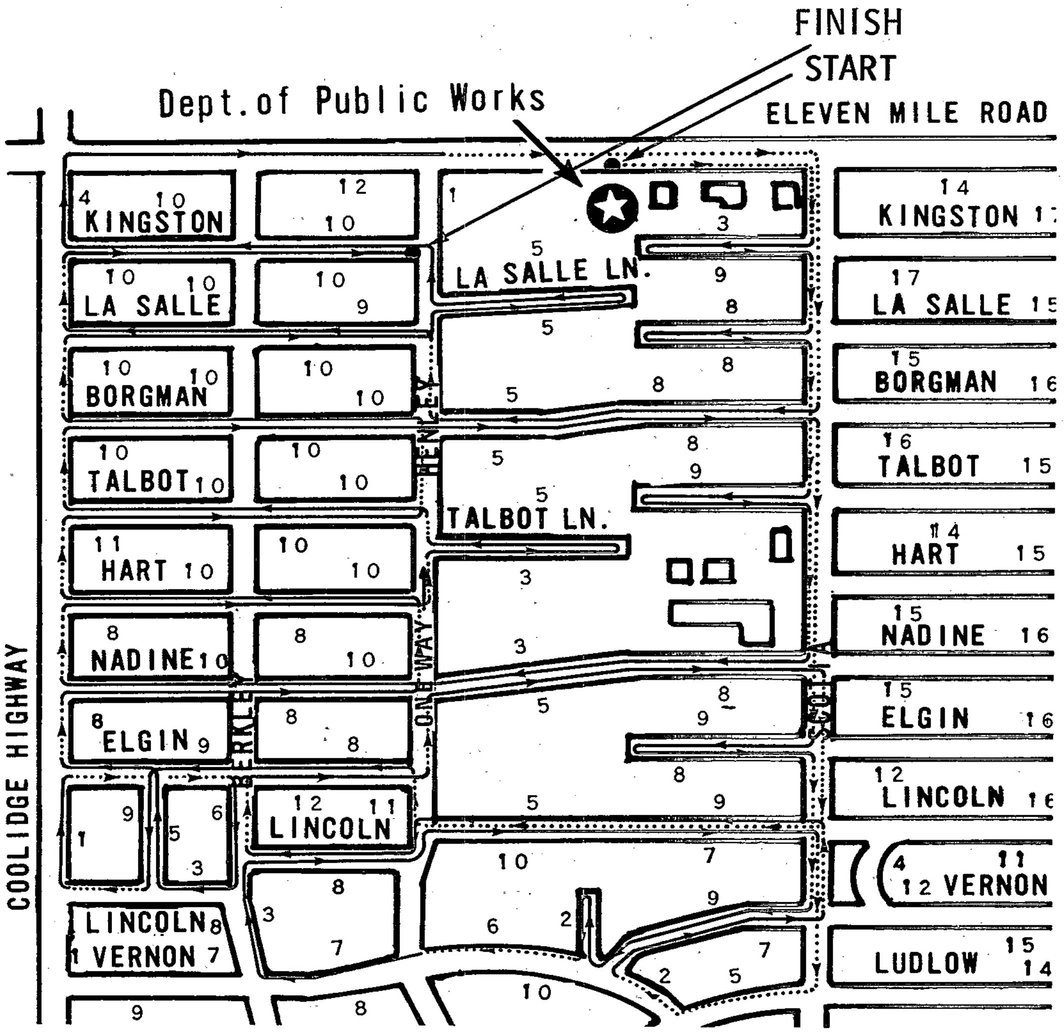


Figure 22. Friday collection route: 494 residences; 16 left turns.

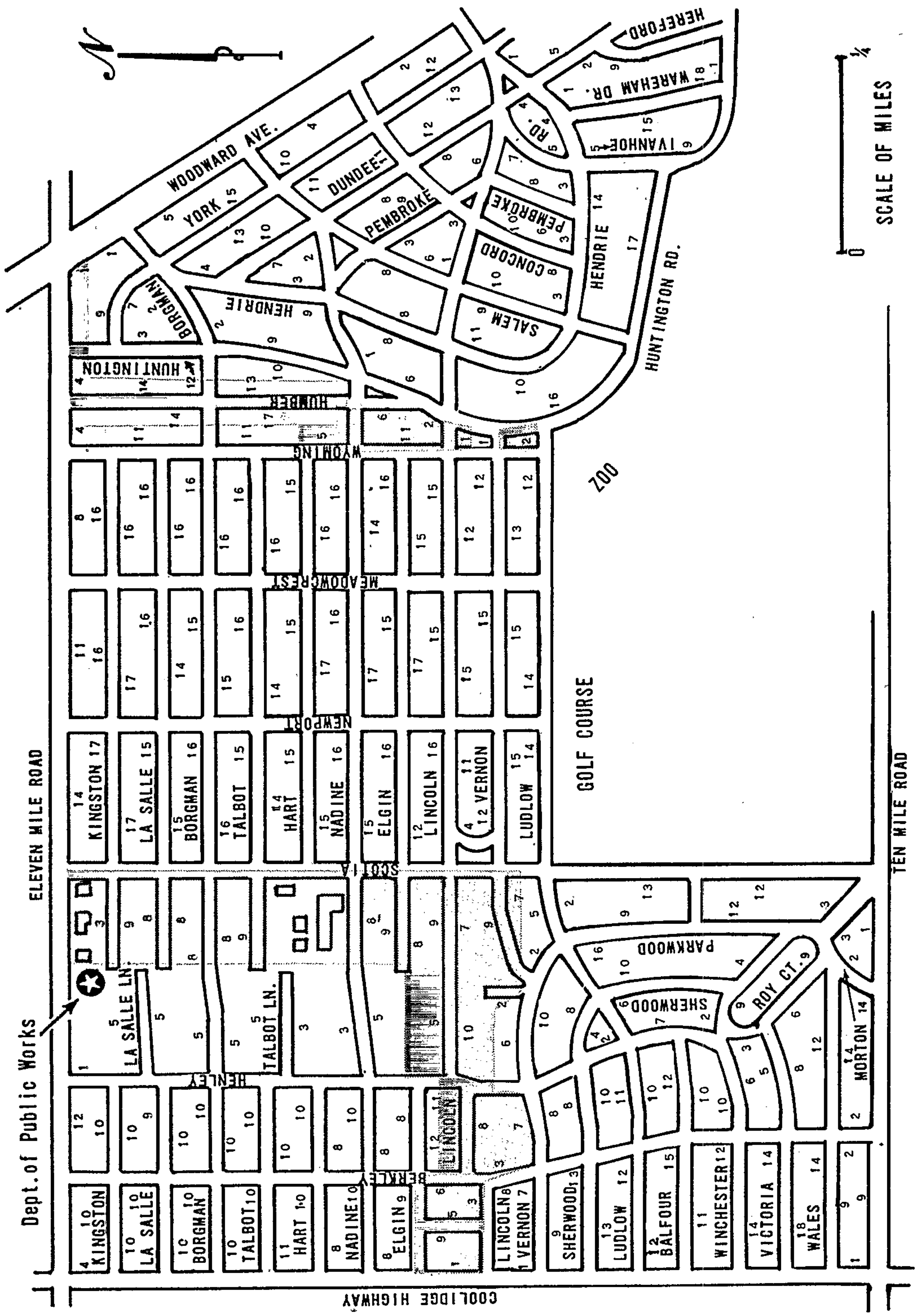


Figure 23. Area of Huntington Woods in which the day of collection was changed because of rerouting.

effectiveness of the micro-routing program

Because micro-routing is the last system design step in the five-stage improvement process and other changes usually take place at the same time, it is difficult to isolate how much of the resultant savings are attributable solely to micro-routing.

In the case of Huntington Woods, for example, three separate changes ensued. First, in 1970, two three-man crews were reduced to two two-man crews. Then, in August 1971, these crews were further reduced to one two-man crew and one one-man crew. Soon thereafter, the heuristic routings were designed for the one-man crew with the two-man crew being eliminated. However, one of the two-man crew was retained as a spare as explained below. The total work force therefore was reduced from six to two men; the number of collection vehicles was reduced from two to one.

Since only the last of the three changes was achieved predominantly through the heuristic routings, the effectiveness of the heuristic routing program is measured by the reduced costs to the City of Huntington Woods *from this third* change.

From 1971 to 1972 the average hourly labor wage increased from $4.42 to $4.77, or 7.9 percent, and the total tonnage collected increased from 3,886 tonnes (4,318 tons) to 4,062 tonnes (4,513 tons), or 4.5 percent. But the total labor charges decreased from $31,309 to $23,700, or 24.3 percent. These labor costs reflect the elimination of one man on the two-man crew, since one individual was retained to fill in for vacations, etc., and for street sweeping and a new separate collection of newspapers. Since the change occurred in the fall of 1971 to distort the 1971 figure, the actual savings in total labor wage reflects a 28-percent reduction, from $32,738 to $23,700. Over the 3-year period, of course, the total savings to Huntington Woods have been much higher.

The effort involved in rerouting the City of Huntington Woods was minimal in view of the cost reductions. The public works superintendent reported that he spent "one day off and on" gathering the required information. The authors of this report spent one day (two man-days) designing the routes and preparing the route book showing each service area and route. The total effort was less than three man-days.

CONCLUSION

To see modern scientific management techniques applied to solid waste management systems is encouraging. Yet, in the case of micro-routing, a less sophisticated, common-sense approach—the heuristic approach—often is sufficient. This approach has the advantage of being a simple tool that can be readily learned and applied by local operating personnel. In addition, it avoids the high cost of existing computer models and gives more flexibility to the routing—a necessity, since communities and routes are so variable. The use of computers or computer models is not to be discredited. Computers have proved useful to solid waste management for billing systems, for storing and manipulating information (the Management Information System for Solid Waste Collection, for example), and for models for more complex procedures such as macro-routing.

The major problem in routing today is that very few communities or collection agencies have ever studied their routings and attempted to improve them. Now that a straightforward, heuristic approach has been developed, more communities can pursue the lower costs and better service that potentially exist for them.

Huntington Woods was a forerunner, but other communities have since used the heuristic approach to routing their solid waste collection vehicles:

Akron, Ohio
Beverly Hills, Mich.
Birmingham, Mich.
Clawson, Mich.
Des Moines, Iowa
East Peoria, Ill.
Fall River, Mass.
Flint, Mich.
Hot Springs, Ark.
Huntsville, Ala.
Lathrup Village, Mich.
Little Rock, Ark.
Portland, Maine
Royal Oak, Mich.
St. Petersburg, Fla.

Each of these cities has realized substantial savings or increased the level of service. Again, not all of the savings necessarily can be attributed to the heuristic routing alone.

EXERCISES

Experience is the best teacher of routing procedures. To provide some practice for the reader, this section contains three exercises to familiarize the prospective router with the heuristic routing techniques. See Figures 24, 25, and 26; each figure is a map that includes all the necessary information and instructions to develop a route. Figure 24 shows a simple block configuration for one route; Figure 25 shows the same block configuration complicated by two one-way streets. Figure 26 shows a complex street layout covering two routes. Figures 27 through 29 present solutions to the exercises.

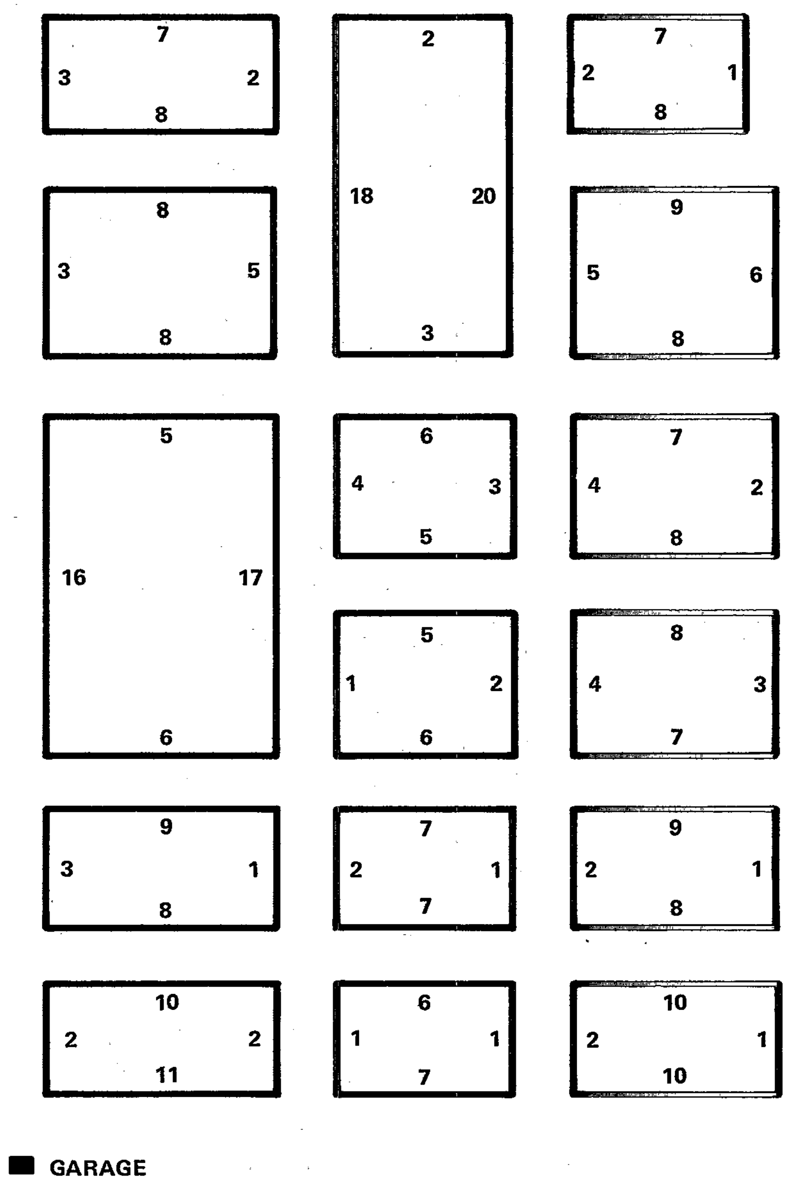


Figure 24. Exercise example: 373 residences; two-way streets.

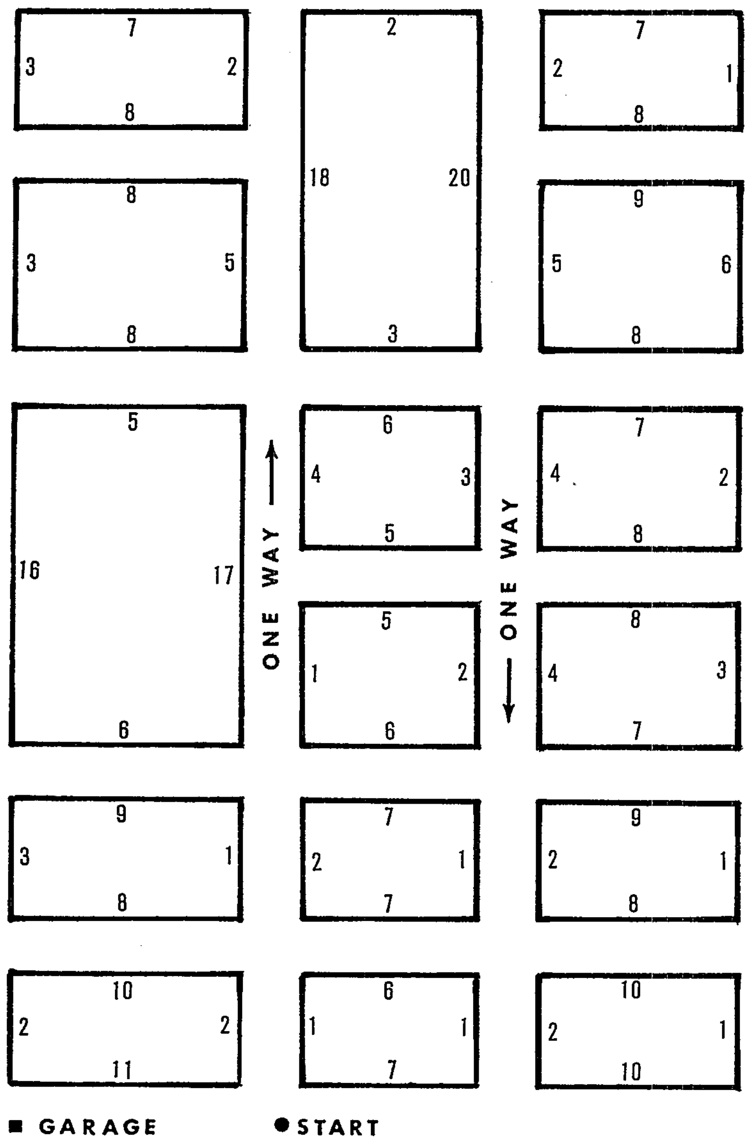


Figure 25. Exercise example: 373 residences; one-way streets.

Figure 26. Exercise example: 997 residences; two collection routes.

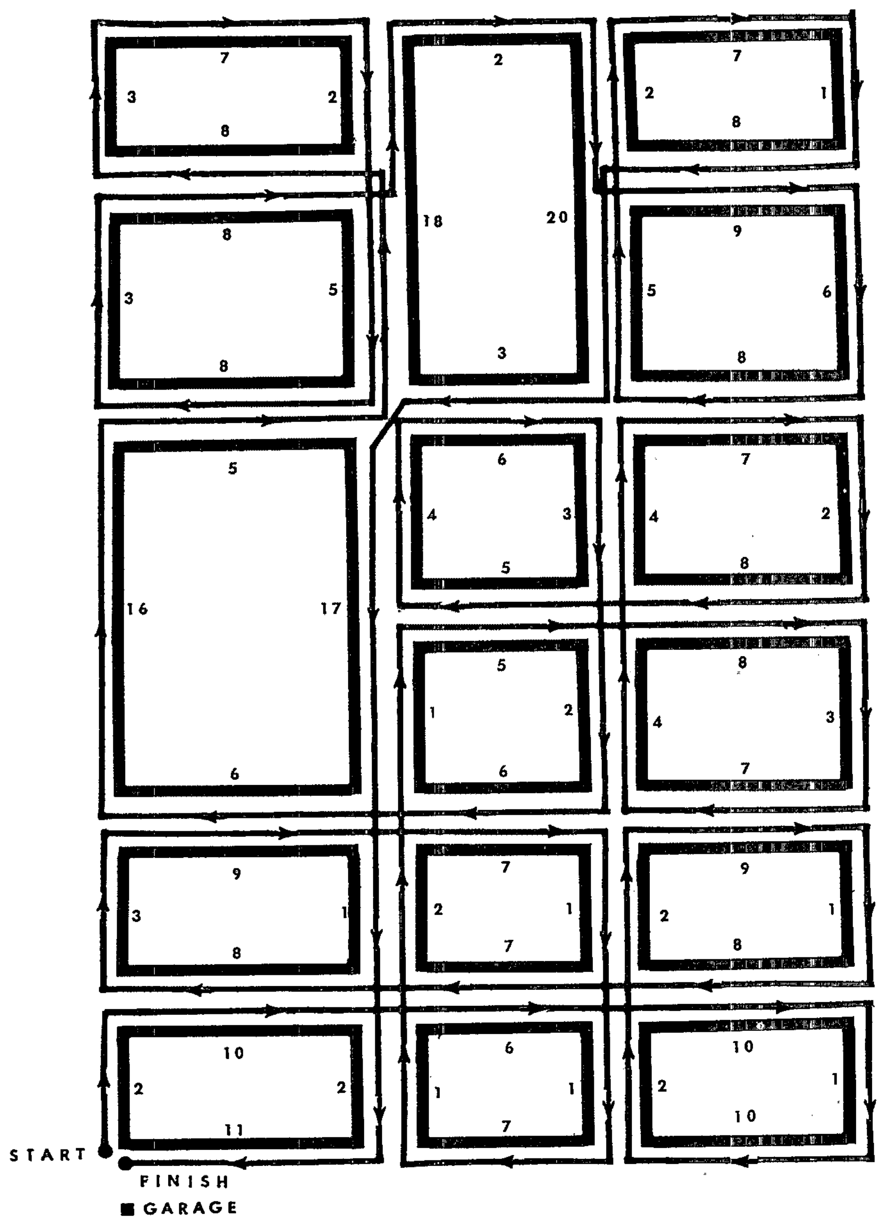


Figure 27. Solution to exercise example, Figure 24. Includes 6 left turns, no dead distance.

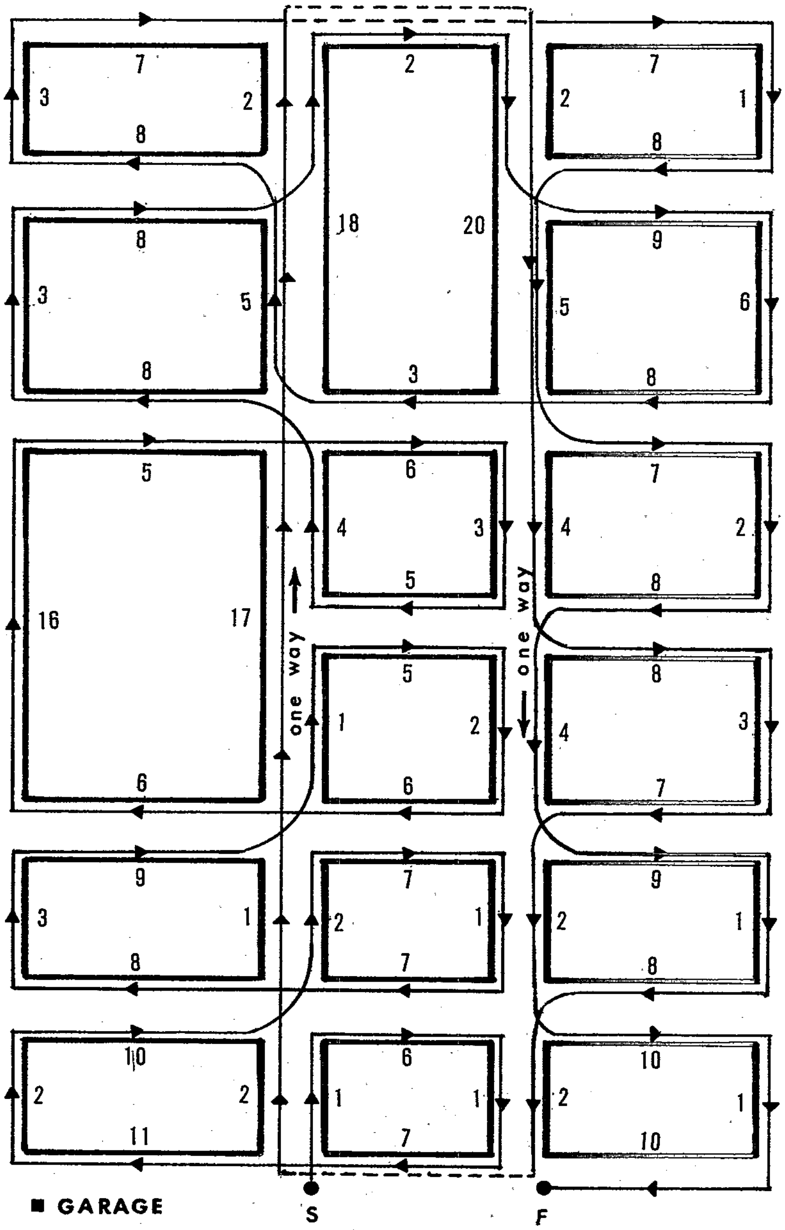


Figure 28. Solution to exercise example, Figure 25. Includes 14 left turns; dash lines represent dead distance.

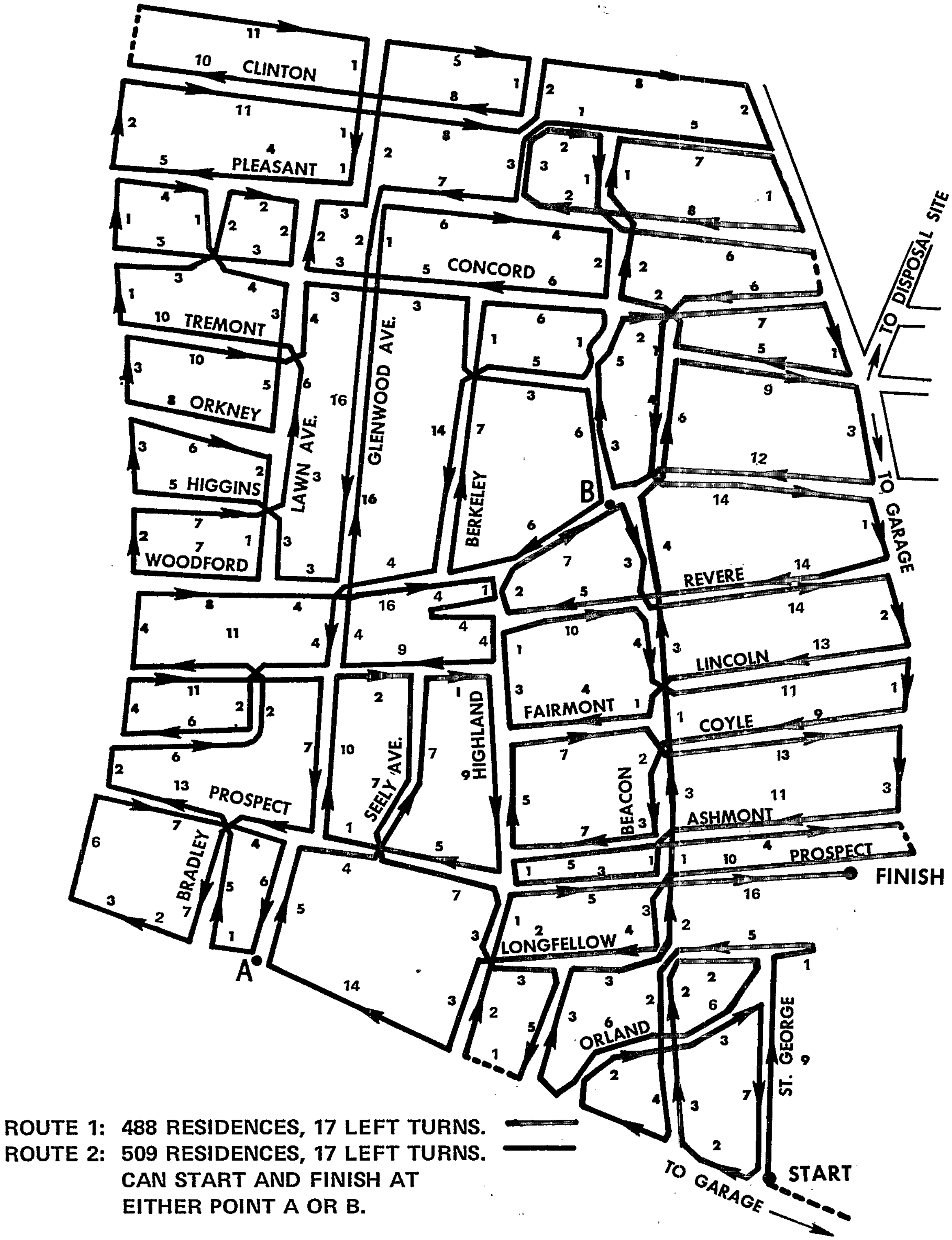


Figure 29. Solution to exercise example, Figure 26. Route 1 serves 488 residences; route 2 serves 509 residences. Each entails 17 left turns.

ABSTRACT

Shuster, Kenneth A. and Dennis A. Schur. *Heuristic Routing for Solid Waste Collection Vehicles,* U.S. Environmental Protection Agency, 1974.

The development and successful application of a heuristic procedure for routing solid waste collection vehicles is described. Topics include (1) the value of routing, (2) reasons for rerouting, (3) advantages of the heuristic approach, (4) heuristic rules, data requirements, and routing procedures, (5) factors to consider when implementing this approach. An actual example and exercises are included to show the relative ease of application and to familiarize the reader with the heuristic approach to the routing of solid waste collection vehicles.

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