RouteSmart TECHNOLOGIES

Utility Meter Route Management and Optimization Using GIS

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Introduction

Gone are the days when "routing" meant colored push-pins on an oversized street map hanging on the wall. Or tracing streets with colored pens on a clear acetate sheet. Or simply counting the number of homes in an area to create a desirable route.

Utility meter reading organizations face an onerous set of challenges in creating and maintaining meter routes. The average meter route comprises 500 stops. Multiply those hundreds of stops over an average of 10 to 12 routes. Then multiply that by an average of 20 to 30 read/billing cycle days. Do the math — all tolled the average utility meter reading problem encompasses over 150,000 reads per month. Too many push-pins.

Complicate the problem further with the vagaries of workload equity among numerous routes, mixed-mode calculations (driving, walking, and combination driving/walking routes), side-of-street specificity, high-density residential and low-density commercial points, and the myriad additional aspects of daily operations and the degree of difficulty multiplies exponentially.

The complexity of these issues veritably precludes creating a routing solution manually. The problem has grown too big, too complex, too unwieldy to be accomplished by hand.

Yet these intricacies and more can be evaluated and resolved more easily using a GIS (geographic information system)-based route-planning application. By leveraging the strengths of a GIS, meter reading organizations reap the abundant rewards this powerful technology offers.

The Challenges

To convey the entirety of the issues faced in route management and optimization for utility meter reading would require a dissertation that far exceeds the scope of this paper. The focus of our efforts herein, therefore, will be to highlight a number of the most challenging issues and to communicate the strengths of a GIS -based solution in solving them. Each of the following aspects of utility meter reading not only benefits from but *requires* a geographic perspective to fully appreciate and address in route optimization.

Bimodal

Meter reading is a bimodal problem, defined as comprising both driving and walking service. But solving a bimodal problem is not as simple, however, as simply defining which meters are read by driving vs. walking, which in itself can be somewhat difficult. Issues related to the bimodal aspect of meter routing, such as the travel time involved in traversing the service area for both driving and walking, optimal parking locations to allow a manageable length of walking before returning to the vehicle, and limiting the amount of non-productive travel time on the route supply an extra level of complexity.

High vs. Low Density

Residential meters present a high-density routing problem, in that a large number of meters are serviced within a (relatively) small geographic area. High-density routing itself can often overwhelm even the most powerful routing applications simply because of the sheer number of meters to be considered for routing. Processing the almost limitless possible combinations of meters in both partitioning (dividing up the service area) and sequencing (determining the most efficient path of travel through each route) a high-density problem can tax the system resources of even today's high-powered computers.

Commercial meters tend to reveal a more low-density problem, but a problem not without its own pitfalls. The meters are often scattered over a wider area, but multiple meters often are clustered closely together in numerous "pockets" throughout the service area, creating a form of high-density routing because of their proximity.

High Precision

Exacting precision is of paramount importance in meter reading routes, and it is often the very technology that we use to make life easier that produces this requirement. The various commercially available handheld units used to capture meter data present the reader with meter after meter in stop sequence on their routes. Therefore, accurate placement of the stops on the map (a process called geocoding) and optimal sequencing of those stops are crucial.

Readers presented with a meter out of the proper sequence must then resequence the route on their handheld units. Nothing dampens the success of a route planning project faster than readers' complaints of out-of-sequence or incorrectly geocoded stops.

Accurate Read Times

Determining the appropriate read or "service" time for each meter is a critical step in the route-planning process. Engineering standards (approximations of meter read times) can be used initially to determine how much adjustment of service times will be needed, but it is safe to say that some adjustment will be required. Whether walking or driving service is indicated will influence service times. And in multi-unit dwellings (such as apartments or condominiums) or large commercial offices, meter banks will have a significant impact on the time spent reading each meter. Even the location of the meter on the property, and whether the meter is inside or outside, can raise or lower the service time accordingly.

Meander/Non-Meander Service

Meander service is defined as traversing a street segment (from one intersection to the next) by zigzagging or crossing the street repeatedly so that in one pass all meters have been read. It logically follows, then, that non-meander service entails reading the meters on one side of a street before crossing to read the other side. The impact of meandering on sequencing options within a route, therefore, is tremendous. But the determination of whether meandering will be permitted is often more a product of safety concerns for the reader than operational goals of efficiency and cost effectiveness, and this requirement often varies from one location to another.

Read/Bill Cycle Days

Cycle days, often called bill or read groups, determine where the meter readers will be on any given day. One of the first steps and primary goals in the route-planning process is often to assess the balance and geographic distribution of the cycle days and to improve these aspects whenever possible.

Balance equates to workload equity and sustainability on a daily basis. Geographic compactness and continuity contribute to route savings and help remediate operational challenges such as labor resource availability variations. If readers call in sick, it's much easier to spread the work around in a tight geographic area. But limiting the potential impact of changing the customer's read and corresponding bill day is frequently a major concern, as this change can cause quite a disruption and customer service headache.

High-Volume Accounts

The heavy consumers of electricity, gas, and other utilities often provide the meter reading organization with "guaranteed" revenue at crucial time periods. These high-volume accounts often are used as "anchors" in route-planning efforts to either even the flow of revenue over a billing period or to produce a necessary spike of revenue at a critical juncture. Maintaining this revenue stream presents an interesting problem for route optimization as these accounts typically cannot be moved from their existing cycle days but must be factored into any new routing scenario.

Natural Boundaries

Rivers, lakes, freeways, and other natural boundaries frequently play a role in both assisting and limiting route optimization efforts. It is often much more efficient to keep a route on one side of a natural boundary, such as a river, because the meter readers often are limited in where they can cross that boundary; if they are forced to cross it, especially more than once or twice, the amount of non-productive travel time in the route will increase. And of course an ancillary benefit of using natural boundaries is that they make it much easier for readers to conceptualize their route service areas.

One of the main goals of any good routing algorithm is to limit the time and distance needed to complete a route; non-productive travel time (time spent traversing the route without reading a meter) simply increases time and expense and should therefore be limited to the greatest extent possible.

Dynamic Problem

Meter reading is not a static operational issue to address once and then consider it solved. Growth in the service area requires that new meters and often new streets be incorporated. It is not uncommon for a meter reading organization to add hundreds of new meters each month. Technological advances also contribute to the changing nature of meter reading route planning. AMR (automated meter reading) is becoming more affordable and practical and impacts route optimization tremendously. Even the change of seasons can influence how routes will be created and maintained. Is it therefore essential that meter reading organizations continually apply a critical eye toward their ongoing route optimization and management efforts.

The Solution

What follows is a discussion of how the application of a GIS (such as ESRI's ArcView GIS) to the varied and numerous issues faced by the utility meter reading industry can have a significant impact on route planning and operational efficiencies.

Bimodal

As stated previously, meter reading is by nature a bimodal (walking and driving) routing problem. But before any route optimization system can determine the optimal routing solution, certain criteria must be specified.

First, the mode of service (walking or driving) must be determined for each meter. This step can be accomplished in a number of ways. A route survey passed to the readers' handheld units can prompt for the mode after each read. This information can be captured and passed back to the GIS for route planning. This approach can be effective, but it requires programming assistance to create and implement the survey and to incorporate the captured data in a new or existing database.

Inherent in a powerful GIS, however, is the ability to calculate the mode of service statistically by determining the density of meters per geographic area and applying a formula to assess whether walking or driving service is appropriate. After calculating the mode for each meter, visual inspection of the results is made possible by classifying the meters by mode on a map to display different colors or symbology for walking or driving service (see Figure 1). Here the power of a GIS enables a meter reading organization to analyze data geographically to set the mode of service, a task that would be impossible using a string-indexing or less powerful map-based application.

Additional "setup" tasks in preparing for bimodal meter route planning are to determine how far the reader can walk from the vehicle, how often the reader will move the vehicle, and appropriate parking locations. Although a powerful route optimization package will calculate these solutions algorithmically, the analysis is made more robust by basing decisions on information derived from and contained within the GIS.

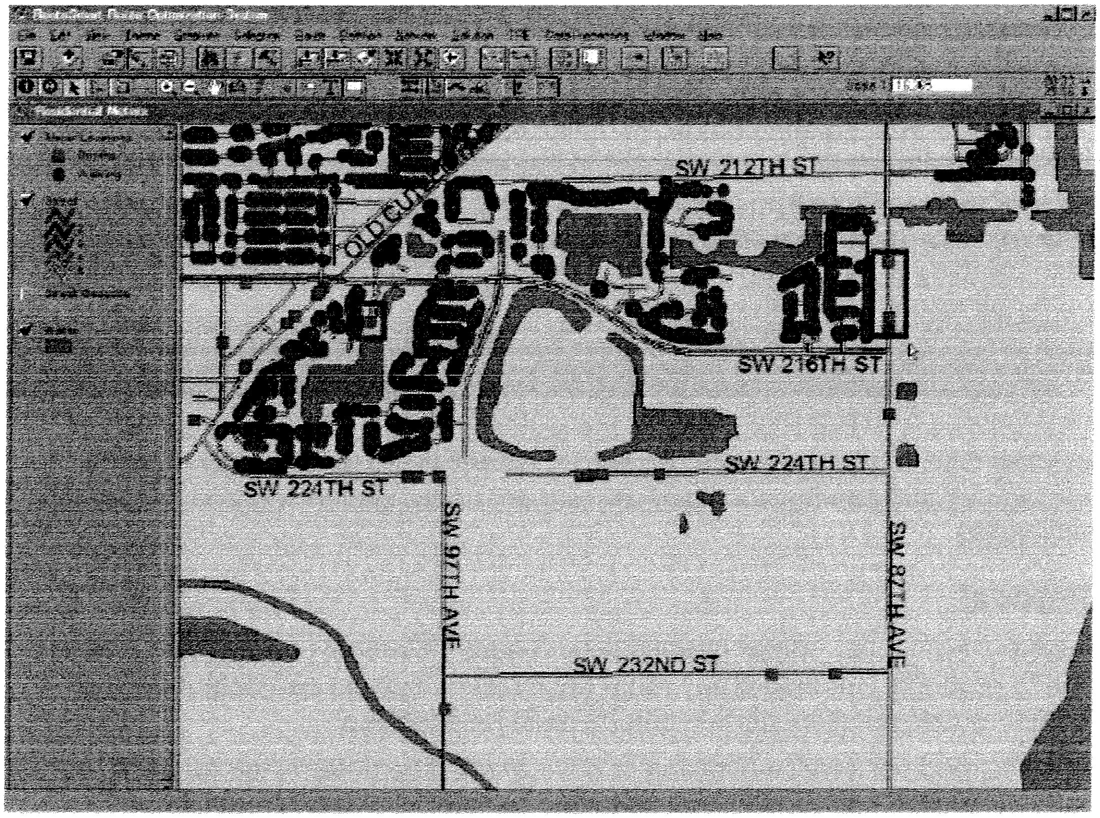


Figure 1: The map shows meter locations classified by mode of service (square = driving, circle = walking). Note that in some areas the density calculation of meters per distance may result in "incorrect" mode settings (black boxes), but visualization of the result in a GIS facilitates quick and easy identification and resolution of "problem" areas. Screen shot from the RouteSmart Route Optimization System, version 4.40.

High Density

The high density of meters in a relatively small geographic area, as can be seen readily in Figure 1 (above), poses numerous challenges to route optimization efforts. First, the sheer number of meters — often exceeding 150,000 for an average size customer, creates a strain on system resources in a PC-based route optimization application. By leveraging native GIS functionality, however, route optimization can be accomplished quickly and efficiently.

But high density problems also carry with them other obstacles to route planning. The task of geocoding meter locations can often be more time-consuming simply because of the large number of meters. ESRI's ArcView GIS offers a powerful geocoding engine that can leverage street names and their aliases ("Main St." also known as "Rt. 14"), plus the capability to edit both the geographic and attribute aspects of the street data.

ArcView also provides the flexibility to geocode to other themes, rather than requiring a street database. For instance, many municipal meter reading organizations can use CAD drawings of parcel themes to overlay on the street data, and leverage a parcel centroid (geographic center point) theme of all possible addresses for geocoding. Of course, once the meters have been geocoded to a parcel theme, a GIS -based route optimization system can spatially join those geocoded points to the actual street network for routing, based on proximity and other attributes, rather than simply using geometric estimates of time and distance as in a non-GIS-based routing package.

Also, high-density typically implies residential service, which implies traversing local roads in a street network to reach those meters. The capability of a GIS-based routing application to use any street database, whether commercial or municipal, increases your data source options and the likelihood that the necessary local roads will be available. Moreover, the GIS allows for the editing and creation of new roads in the street network, the benefit being that limitations of the data need not be roadblocks to successful route planning.

High Precision

Precision is absolutely essential in a high-density routing problem like utility meter reading, not only in the placement of meters along a street segment, but also in determining the appropriate side of the street. Sequencing meters correctly without knowing precisely where they are located is an impossible task, and a GIS provides the tools to ensure that level of precision.

Once meters are geocoded, classifying and coloring those meters on a current route value or other meaningful attribute enables a quick and easy visual verification of the geocoding process. Incorrectly geocoded meters appear as glaring exceptions outside the anticipated route area and can then be moved to the appropriate location.

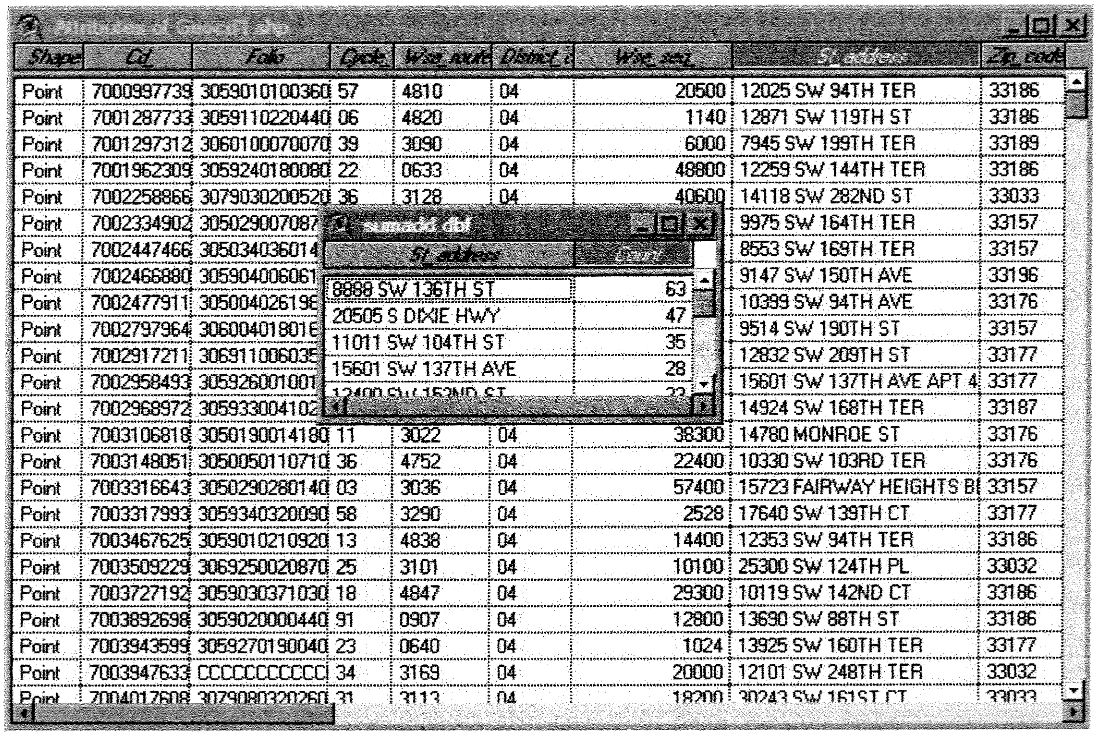
Incorrectly geocoded meters lead to inaccurate routes and sequences, which lead to unhappy meter readers who are forced to resequence their routes in their handheld units. Getting it right the first time prevents this problem from occurring and encourages employee buy-in of the routing solutions.

Accurate Read Times

Obtaining accurate service times for each meter can be a challenge. Often organizations will use elapsed time from one read to the next obtained from the readers' handheld units. This method can work well for the majority of meters if the data is available, but it doesn't take into account any variables such as readers taking breaks or encountering difficulties with a particular read and can therefore be misleading.

Another option is to proceed with engineering standards for read times — basically applying an average read time for meters across the board. This method also can be effective but has its shortcomings as well.

Assume a route contains 500 meters. If the average read time was 30 seconds, the route would entail approximately 4 hours and 10 minutes of read time, travel time comprising the remainder of the route. But what if the route contained a stop at a condominium or large office building with 100 meters at that single address? If we assume it takes 30 seconds to access and read the first meter, and then only 5 seconds per additional meter after that, the route becomes approximately 41 minutes shorter. The time spent reading a bank of meters is much less than the time spent reading one and walking to the next, so the impact on the total time of the route can be significant.



Shape	Cd_	Folio	Cycle_	Wse_route	District_c	Wse_seq	St_address	Zip_code
Point	7000997739	3059010100360	57	4810	04	20500	12025 SW 94TH TER	33186
Point	7001287733	3059110220440	06	4820	04	1140	12871 SW 119TH ST	33186
Point	7001297312	3060100070070	39	3090	04	6000	7945 SW 199TH TER	33189
Point	7001962309	3059240180080	22	0633	04	48800	12259 SW 144TH TER	33186
Point	7002258866	3079030200520	36	3128	04	40600	14118 SW 282ND ST	33033
Point	7002334902	305029007087					9975 SW 164TH TER	33157
Point	7002447466	305034036014					8553 SW 169TH TER	33157
Point	7002466880	305904006061					9147 SW 150TH AVE	33196
Point	7002477911	30500402619E					10399 SW 94TH AVE	33176
Point	7002797964	30600401801E					9514 SW 190TH ST	33157
Point	7002917211	30691100603E					12832 SW 209TH ST	33177
Point	7002958493	305926001001					15601 SW 137TH AVE APT 4	33177
Point	7002968972	305933004102					14924 SW 168TH TER	33187
Point	7003106818	3050190014180	11	3022	04	38300	14780 MONROE ST	33176
Point	7003148051	3050050110710	36	4752	04	22400	10330 SW 103RD TER	33176
Point	7003316643	3050290280140	03	3036	04	57400	15723 FAIRWAY HEIGHTS B	33157
Point	7003317993	3059340320090	58	3290	04	2528	17640 SW 139TH CT	33177
Point	7003467625	3059010210920	13	4838	04	14400	12353 SW 94TH TER	33186
Point	7003509229	3069250020870	25	3101	04	10100	25300 SW 124TH PL	33032
Point	7003727192	3059030371030	18	4847	04	29300	10119 SW 142ND CT	33186
Point	7003892698	3059020000440	91	0907	04	12800	13690 SW 88TH ST	33186
Point	7003943599	3059270190040	23	0640	04	1024	13925 SW 160TH TER	33177
Point	7003947633	CCCCCCCCCCC	34	3169	04	20000	12101 SW 248TH TER	33032
Point	7004017608	3079080320260	31	3113	04	18200	30243 SW 161ST CT	33033

St_address	Count
8888 SW 136TH ST	63
20505 S DIXIE HWY	47
11011 SW 104TH ST	35
15601 SW 137TH AVE	28
12400 SW 152ND ST	22

Figure 2: ArcView's Summary feature can identify addresses with multiple meters (meter banks) for calculating more accurate service times. Screen shot from the RouteSmart Route Optimization System, version 4.40.

This scenario is not uncommon and exemplifies the benefits of using a GIS. Using ArcView's Summary feature on the meter address field, a quick determination can be made of those addresses where meter banks are present (see Figure 2). And using the spatial analysis tools in the GIS can facilitate the identification of meters at the same geographic location. Then a short formula can be used to apply more accurate read times to these multi-unit addresses. The strength of the GIS is that it combines database and spatial tools to enable multifaceted analysis of both data and geography; the geographic component contributes a crucial dimension that leads to better results.

Meander/Non-Meander Service

Determining meander (zigzagging or repeatedly crossing a street) versus non-meander service can have a significant impact on route planning results. The path a route will take will be dramatically different depending on whether meander is permitted, and a powerful, GIS-based route optimization system will model this scenario. Again, the decision to allow meander service is most often based more on reader safety concerns than on gaining operation efficiencies, but a GIS makes the decision easier.

An easy way to begin examining meander service is to classify or color service area streets by functional class or speed category. This step creates a map display that makes it easy to identify local roads versus collectors versus highways and other classes. Once the classification is complete, ArcView GIS provides a query function to select certain streets by functional class. If meander is permitted in the service area it is most likely allowed primarily on local roads where less danger exists for the reader in crossing the street. If meander capability is applied globally to all local streets, the GIS can then be used to classify streets by meander or non-meander, where visual inspection can help determine exceptions (see Figure 3).

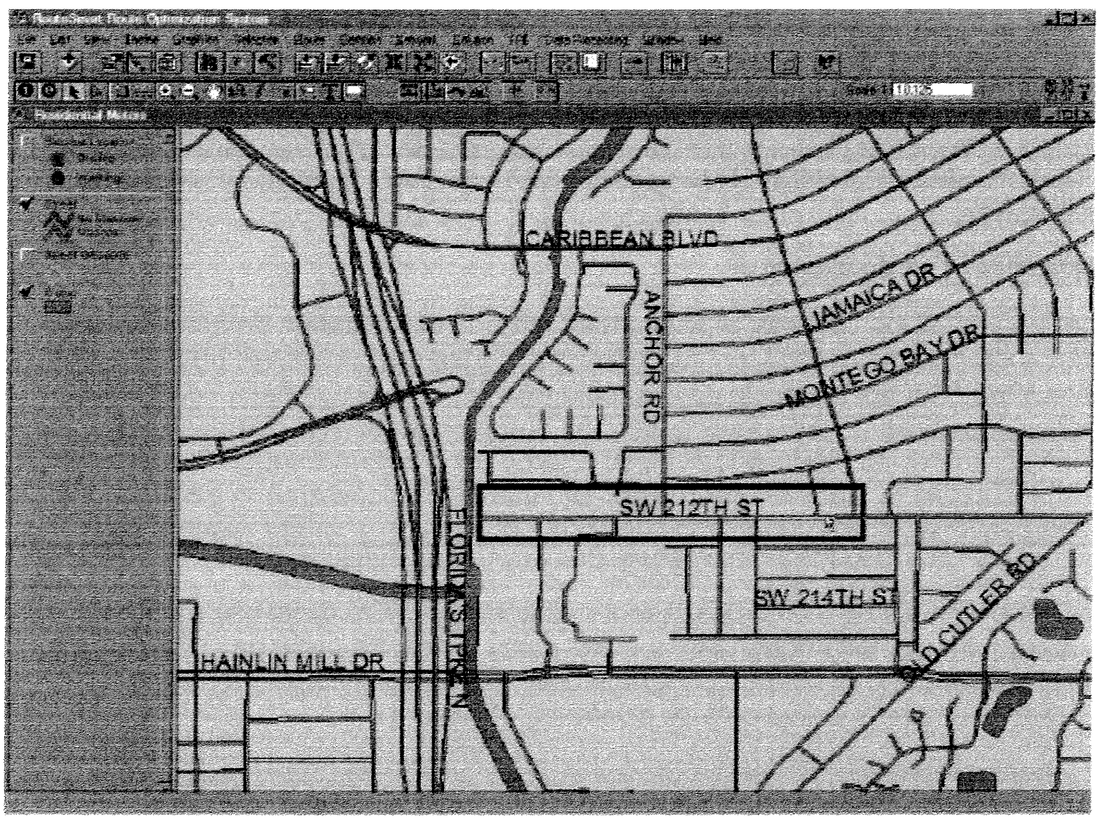


Figure 3: Classifying the streets by meander revealed a busy street where the reader should not cross the road (black box). The attributes of this street can be changed to deny meander service for reader safety. Screen shot from the RouteSmart Route Optimization System, version 4.40.

More important, though, is that the GIS can leverage topographical analysis, not possible in non-GIS systems, to help determine meander settings in scenarios such as that illustrated in Figure 4. Streets such as cul-de-sacs or courts should not be serviced by meandering simply because the topology of the street (only one way in and out) requires that a reader traverse that street segment twice.

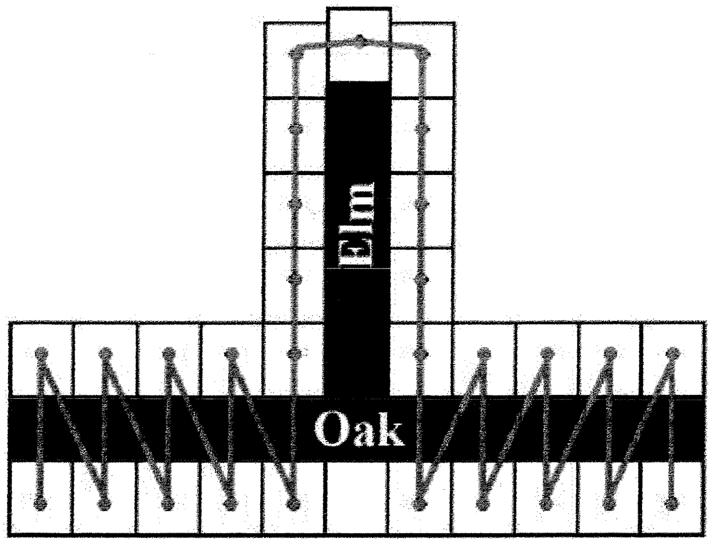


Figure 4: The meters on Oak Street could be serviced by meandering, but the meters on Elm Court should be serviced on one side and then the other, simply because the topology of the street demands that the reader walk back along the same street segment to leave the street. The GIS could be used to analyze the street topology for exceptions such as this.

Read/Bill Cycle Days

The reading/billing cycle for a utility meter reading organization determines how often customer meters will be read and when those customers will be billed, but more often than not the cycle days should also represent compact, contiguous geographic areas. The benefits gained by grouping areas into compact cycle day areas are many, including a logical, structured progression through the service area; the ability to more readily redistribute meter workload among existing resources if necessary; a more manageable dispersion of meter readers on a daily basis, and of course, cost savings and increased efficiencies.

The benefits of using a GIS-based tool to determine these cycle day partitions also are many, chief among them the ease with which the cycle day distributions can be viewed and evaluated geographically to ensure minimal interlacing (overlap of day areas) and optimal clustering of meters.

Of course, the operational realities of changing customers' read and bill days cannot be overlooked. A significant additional benefit of using a GIS-based route optimization system is the ability to model any number of routing scenarios for comparison.

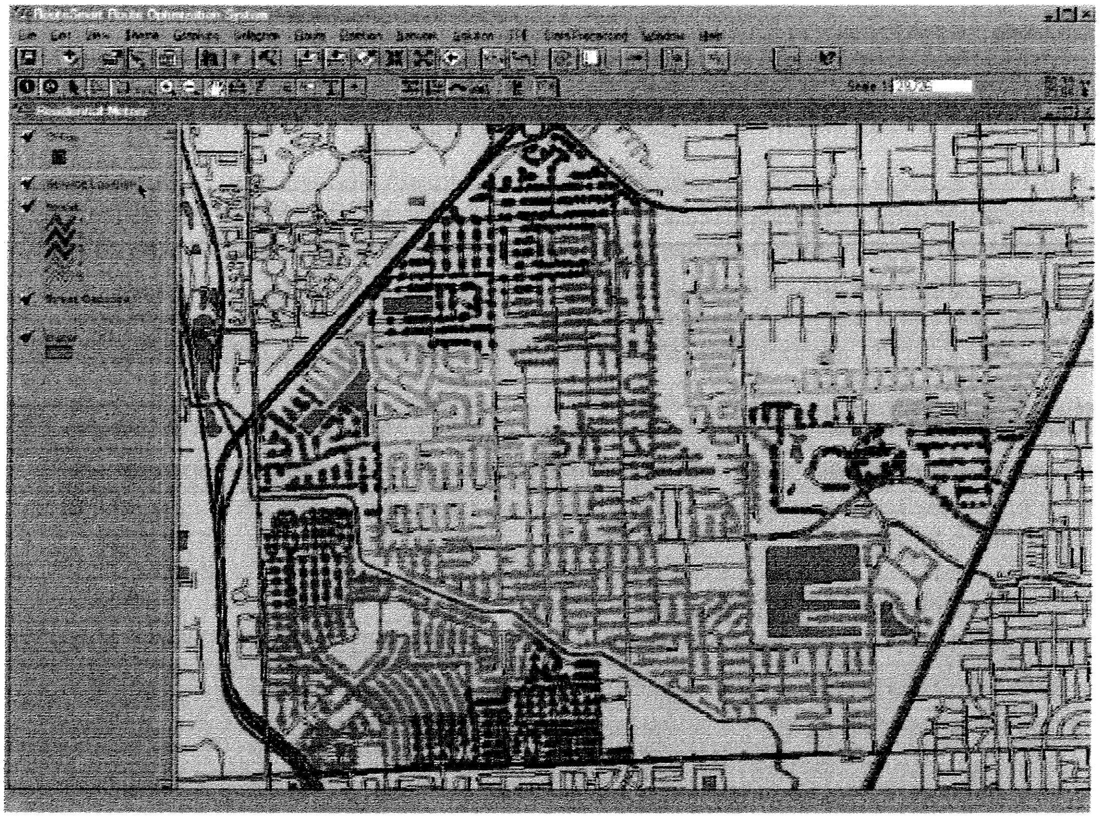


Figure 5: A collection of stops colored by read cycle days after optimization. Note the minimal degree of overlap and tight clustering of the cycles, which results in operational efficiency and cost savings. Screen shot from the RouteSmart Route Optimization System, version 4.40.

A common approach to evaluating whether read and bill day changes will be implemented is to first proceed with intra-cycle day route optimization, or basically creating balanced and efficient routes within existing cycle days. Balance between the cycle days is ignored in this first step in an effort to minimize the disruption and make any route changes transparent to the customer.

Once the results from this initial scenario have been examined, that solution can be saved and a second scenario can be run allowing the system to also improve the balance between days but limiting the extent of the changes as much as possible. A third and even a fourth or more scenarios can be run, each iteration allowing the system increasing degrees of freedom in creating balanced cycle days. The results from these various scenarios can be compared, and the cost and efficiency gains can be weighed against the potential disruption to the customer.

High-Volume Accounts

High-volume users of utilities often comprise a significant portion of the ongoing revenue for utility organizations. These "heavy-hitters" typically function as anchors for route planning efforts in that the utility has identified when the revenue from these customers will yield the greatest benefit, whether they are used to even the revenue flow throughout the month or to provide a "shot in the arm" during a critical period, such as preceding payroll or A/P processing.

By including a geographic component to examining the placement of the high-volume accounts in appropriate cycle days, the GIS in conjunction with a route optimization system presents the ability to use these customers as "seed points" within the days, around which the rest of the cycle day can be built. In this manner the utility can be assured of maintaining the revenue flow they need while still realizing the positive results of partitioning and route optimization.

Natural Boundaries

Any sophisticated route optimization system will take into consideration most significant natural boundaries, simply because the boundaries tend to affect the street network and limit travel path options. A GIS-based route optimization system, however, provides even more flexibility in incorporating natural boundaries in route planning efforts.

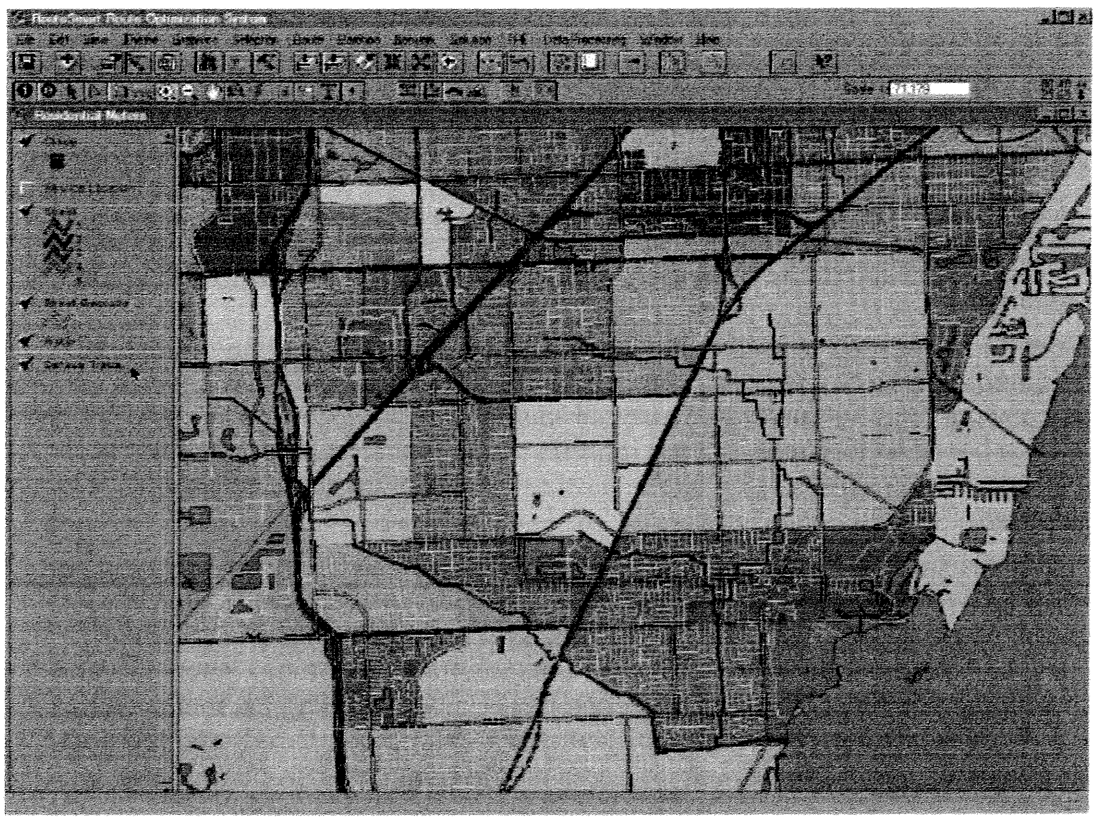


Figure 6: The service area colored by census tracts. The polygons can then be used for subdividing meters into meaningful areas, as is possible with any appropriate polygon theme. Data source for free census tract polygons: U.S. Bureau of the Census, 2000, obtained via ESRI's Geography Network (www.geographynetwork.com). Screen shot from the RouteSmart Route Optimization System, version 4.40.

In a GIS, multiple layers or themes of data can be displayed in relation to a meter service area. Incorporating themes of water, railroad tracks, major highways, or even ZIP code or census tract data (see Figure 6, above) can provide a perspective impossible to achieve in a non-GIS-based system. Once displayed, these features can be used to help define subsections of a service area or as a means of selecting a subset of meters within an area for route planning. These features can also be set up as barriers to help define work or route areas within the larger service area.

Dynamic Problem

Meter routes are not static. New homes and businesses appear with almost alarming rapidity, forcing the re-examination of meter routes on a regular basis. It is not uncommon for a utility meter reading organization to add 500 – 1000 new meters per month to the existing service area. With this degree of flux, existing routes can become out of balance and inefficient rather quickly, but a GIS-based route optimization system provides a number of tools to facilitate incorporating this high volume of new meters.

A powerful route optimization system will allow modeling of a number of different scenarios, which can then be compared and evaluated on selected criteria to arrive at the most palatable solution. Therefore, from the baseline of the existing routes, the addition of new meters can be analyzed so that the impact of the changes is minimized to the greatest extent possible.

In a GIS-based system, route changes are made easier through a combination of geographic attributes and algorithmic solvers, as well as the ability to inspect the results visually. Route planners can incorporate new meters into existing routes using work-area design concepts and techniques, and then quickly determine "problem" areas requiring either automated or manual interaction to achieve a more balanced and efficient solution.

And of course, a GIS-based system provides increased speed and efficiency in route planning itself, enabling a route planner to model multiple scenarios with varying criteria to produce the desired result. Attempting to model route changes without the benefit of a GIS leaves the route planner both frustrated and in the dark. The time involved in creating new routes by hand is at the very least prohibitive, and without the geographic analysis component made possible by a GIS it is highly unlikely that an optimal solution can be reached.

Other Benefits of a GIS

Data Preparation

A strong differentiator between a GIS-based route optimization system and other map-enabled routing packages is the cadre of ancillary tools available to facilitate route planning efforts. A perfect example of this strength lies in data preparation, or acquiring and preparing data for optimization.

Geocoding (placing the meter locations on the map) is often one of the most time-consuming steps in route planning. Meter address data must be accurate, and those addresses must match the data present in the street data or other address-based themes, but often there is a disconnect. When this data is either not present or incorrect, basic map-enabled routing packages force the user to place those meters on the map manually, using a "point-and-shoot" technique. Median meters, highway sign meters, and others often fall into this category as the meters tend to be missing specific address data.

Although this "point-and-shoot" technique is available and easy to use in GIS-based systems as well, consider the high-density problem of meter reading in general. When the number of meters can often exceed 150,000, even a 99% geocoding match rate leaves 1500 meters ungeocoded. And a more typical "good" match rate would be more in the neighborhood of 94% - 97%, potentially leaving up to 9000 meters to be placed manually.

In a standard, map-enabled routing package, there is typically very little choice at that point — either put the meters on the map by hand or leave them unrouted. But with a GIS-based system, tools like ESRI's ArcPad application can be used to quickly and easily capture the geographic location of these "problem" meters.

ArcPad is a field data collection tool that puts a GIS in the palm of your hand. Load ArcPad onto any of today's high-powered Windows CE devices, such as the Compaq iPAQ, add a GPS (global-positioning system) device, and with minimal effort the data is captured and can be incorporated with the geocoded meters for route planning and analysis.

Solution Analysis and Manipulation

The myriad operational details discussed in this paper make it intractable to optimize even a moderately-size routing problem. Fortunately, however, a good route optimization system will make use of efficient heuristic algorithms to provide *near-optimal* routing solutions. Then, the near-optimal solutions from the route optimization system can be easily displayed inside the GIS, where the route planner is provided with analysis tools that far exceed the capabilities of a non-GIS-based route optimization system.

Starting with the *near-optimal* solutions from the route optimization system displayed using the GIS, the route planner can make use of graphical swapping, point-and-click resequencing, or sub-area reoptimization to refine the initial solution provided by the route optimization system. The visual power of the GIS thereby allows the route optimization system to provide very fast, near-optimal solutions that can be easily refined by the route planner.