Web-Based Vehicle Routing Solutions for Waste Management, Inc.

Bob Kraas, MBA, MA, Surya Sahoo, Ph.D., P.E., C.V. Ramanakumar, M.S., Mansour Raad, M.S., Seongbae Kim, Ph.D., Byung-In Kim, Ph. D.

Abstract

Beginning in early 2000, Waste Management, Inc. (WM - http://wm.com) executives realized the need to reduce the inefficiency of the vehicle routes. As the solution provider, Institute of Information Technology, Inc. (IIT - http://e-iit.com) developed efficient routing algorithms taking into consideration various business requirements, such as multiple vehicle disposal trips and material type limitations, and incorporated them with the Internet-enabled enterprise GIS called WasteRoute™. WasteRoute™ was deployed across the nation beginning March 2003, with a net effect of 984 fewer routes at the end of the year, resulting in a savings of $18 million. Estimated over the course of the entire year for 2004, this translates to a savings of $44 million. This paper focuses on the importance of ArcSDE and ArcIMS to establish an enterprise GIS and incorporation of IIT's routing algorithm, which is crucial to the success of a web-based enterprise vehicle routing solution.

Waste Management Background

WM is the leading provider of comprehensive waste management services in North America. Headquartered in Houston, the company's network of operations includes 293 active landfill disposal sites, 16 waste-to-energy plants, 72 landfill gas-to-energy facilities, 146 recycling plants, 346 transfer stations and 435 collection operations (depots). Combined, these resources enable WM to offer a full range of environmental services to nearly 20 million residential and two million commercial customers throughout the U.S. and Canada.

WM provides solid waste collection services for residential, industrial, municipal and commercial customers in 48 states, the District of Columbia, Canada and Puerto Rico. With nearly 26,000 collection and transfer vehicles, it operates the largest trucking fleet in the waste industry and collects over 80 million tons of solid waste each year. The company serves more than 20 million customers who represent a wide range of services, from picking up household trash at a single-subscription residence, to providing comprehensive waste programs for large national customers with hundreds of locations. For these companies, the national accounts department provides expertise to develop customized programs, and a WM representative often works on-site to help manage the specialized and diverse environmental needs of a large industrial company.

The Problem of Routes

While transitioning from a decentralized to centralized organization, WM recognized that managing the daily activities of its 19,600 daily routes was not a trivial task. It is typical for WM to operate vehicles six days a week. Few vehicles operate on Sunday. With each vehicle approaching an approximate annual operating cost of $120,000, WM had a good reason to make every daily route as profitable and efficient as possible. It was the intention of WM management to reduce the overall operating expenses. The key contributors to cost are fixed vehicle cost, variable vehicle cost and labor expense. It was determined the best way to evaluate the results of the program was to measure the reduction of vehicles. When reducing one vehicle, the result may reduce five or even six route days. The unequivocal result is the reduction of assets. To begin to understand the daily operations, we first must understand each line of business. The collection business is divided into three major areas: commercial, residential and industrial. Each area includes municipal solid waste and recycling material, and each is very different from the others.

The single largest differentiator between residential and commercial routes is the mandatory adherence to driving on one side of the street. Unlike commercial routes, residential routes are only permitted to service customers on the right side of the street (Figure 1).

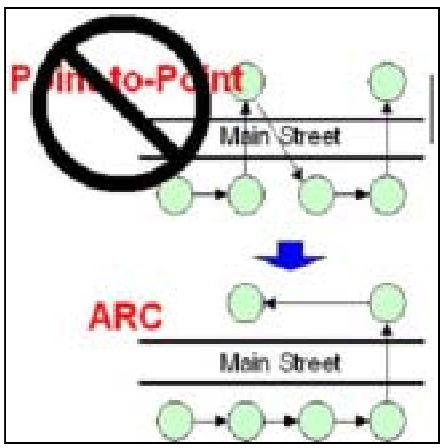

Figure 1: Residential collection requires arc routing

Very few exceptions are granted for alleys and one-way streets. This meant that solving the residential routing problem would be very different from the commercial method. It is perfectly acceptable to use a point-to-point solution for commercial routes, while an arc-routing model is required for residential routes.

Industrial routes introduce a different routing problem. The differentiator between industrial and commercial is the size of the container. A typical commercial container is eight loose yards, while an industrial container may range from 20 to 40 loose yards and only one container may be serviced at a time. While hauling these large containers, it is common for each container disposed of and returned to the original customer's location. To complicate the problem, many different approaches are used to make this operation more efficient. One example of servicing the customer would be to first deliver an additional empty container at the customer location, pick up the full container, travel to a disposal facility and then dispose of the contents. At this point, the vehicle may service another customer with the same size container. The difficulty arises when a driver is scheduled to perform different types of services throughout the day to customers with different container sizes and different service requirements. Driver-experience level, vehicle types, container types, material types and security clearance are all contributing factors when creating industrial routes.

Both residential and commercial collection problems can be classified as a variation of vehicle routing problems with time windows (VRPTW), but with additional constraints. In the literature, a typical vehicle routing problem (VRP) is comprised of a set of vehicles, stops, and a depot. Each vehicle starts from the depot, visits a number of stops, and ends at the depot. Depending on the nature of each application, VRP may possess different characteristics, including types of vehicles (homogeneous or heterogeneous) and number of depots (single or multiple). VRPTW is defined as VRP extended by additional time constraints associated with each stop. Similarly, the depot also has a time window. Each vehicle has a single capacity constraint, such as maximum volume or maximum travel time. The objective function(s) generally minimizes total costs – total travel time. The VRPTW is NP-hard and finding a feasible solution with a fixed fleet size is an NP-complete problem (Cordeau et al., 2002), and one frequently resorts to approximate or heuristic procedures in solving the problem.

As with a typical VRPTW, at WM, it is assumed that there is a single depot per site, an operational area (such as a city or county), a finite number of homogeneous vehicles, a set of stops, and landfill facilities. Landfill facilities are the unique feature in the waste collection business. The constraints specific to landfills are a major component of the routing model for waste collection companies. When a vehicle is full, it needs to go to the closest available disposal facility. Each vehicle can, and typically does, make multiple disposal trips per day.

WM selected IIT as a Solution Provider

WM organized a team of stakeholders and consultants to evaluate best-of-breed route management software packages. WM was looking for an application that could be integrated into their existing IT infrastructure and with a preference for web-based solutions.

WM decided that the best way to evaluate the 19 vendors was to put them head-to-head in a competitive situation. This competition occurred in Houston during August 2001. The final evaluation to compare the quality of the routing algorithm engines was conducted in February 2002. The purpose of the test was to evaluate and compare the functional fit of the algorithms into WM's business rules. Results of the algorithm test were evaluated on the basis of meeting three fundamental objectives: 1) route reduction (cost savings), 2) workload balancing (number of routes) across days of the week, and 3) adherence to business constraints. Institute of Information Technology, Inc. (IIT)'s solution adequately accounted for these requirements.

In March 2003, three months after initial development began, WM rolled out the first version of WasteRoute™.

GIS and Optimization

A Geographical Information System, or GIS, is an information system in which spatial information is tightly integrated to the managed data. To illustrate the contrast, consider a customer in a standard relational database. A typical set of attributes for a customer would include name, billing information and address information. The address information is typically entered manually in a customer relationship management system and its use is typically relegated to mailings. Used solely in this manner, it is difficult to determine the proximity to other customers or routes, resulting in less-than-effective-decision support.

In a GIS, the customer's address is used as a basis for generating spatial information about the customer. This spatial information includes the specific x, y, and z location of the customer in a coordinate system. It also includes the geometry of the customer, which, although typically a point, could also be a line or a polygon. When this spatial information is brought together with other information having spatial components, such as streets, truly unique aspects of the data can be viewed and utilized. For example, the customer can be displayed on a map on which a user can see the location with reference to the surrounding street network, various landmarks, other customers or the collection facility.

Although the application developed for WM by IIT allows users to view customer locations on a map and do spatial manipulations of the information, the true power of GIS is evident when constructing a key component of the optimization engine, an origin-destination matrix (OD). This matrix simply captures the distance and time between any two given points. Using a GIS to generate the OD, however, makes the distances and times captured in the matrix much more accurate than other distance calculation techniques. The GIS allows the distances to represent the exact distances as traversed on a street network, taking into account various constraints that all contribute to generating a realistic result, including speed limits, directional attributes of the streets (such as one-way direction or turn penalties/restrictions), and accurate segment distances. The increased quality of the OD results directly in solution candidates that are less likely to be discarded due to practical infeasibilities. The solutions generated by the IIT optimization engine are also more likely to constrain routes accurately when employee considerations (such as workday hour limit, breaks and disposal trips) are taken into account.

The WasteRoute™ System

WasteRoute™ is a web-based application, designed and developed as a Java application. The technical architecture of the system is illustrated in Figure 2. The WasteRoute™ system also integrates with other systems within WM (Figure 3). The user interface is managed by applets, is launched from a web page, and runs within the Java Virtual Machine found in nearly all web browsers.

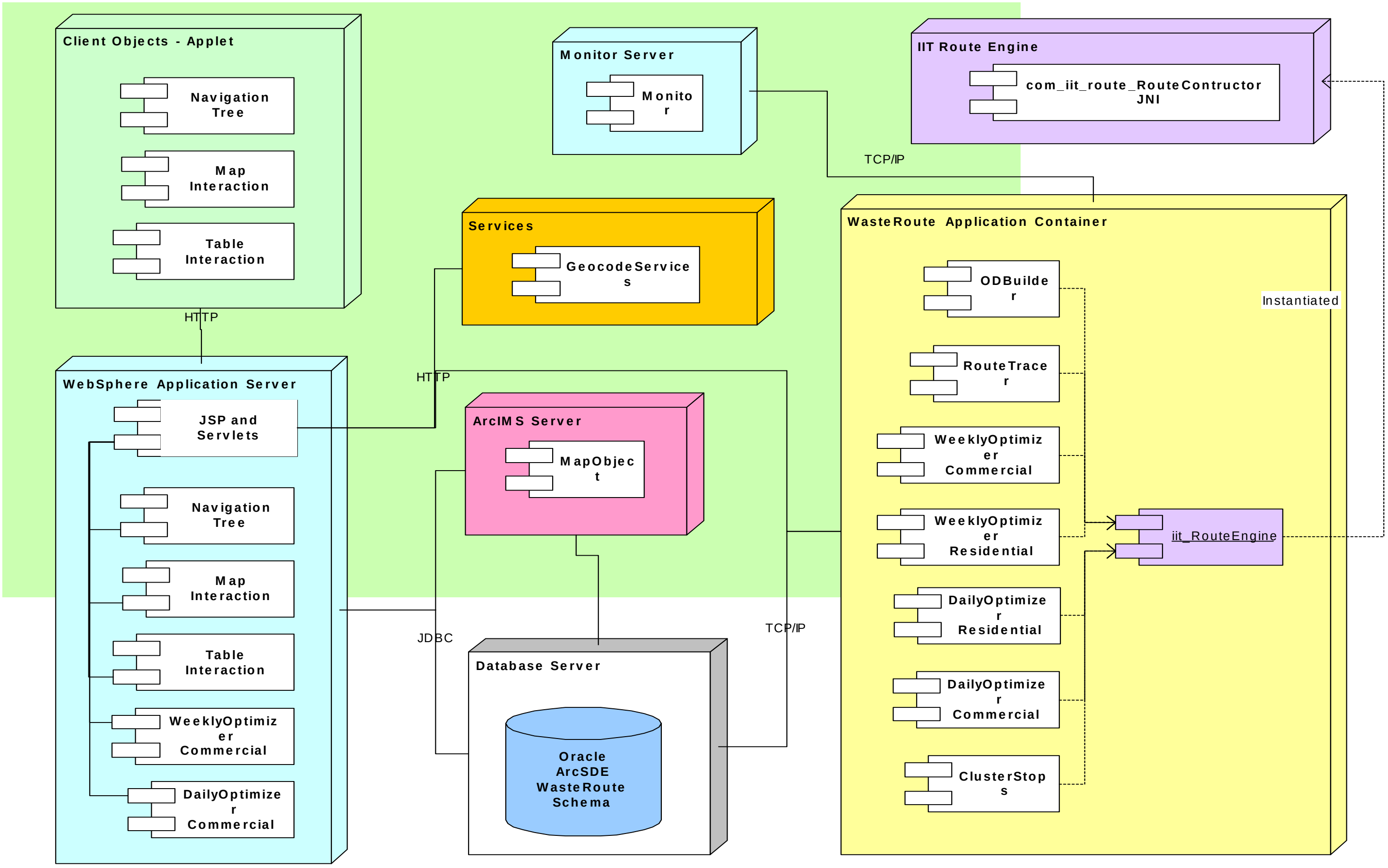

Figure 2: Technical Architecture of WasteRoute™

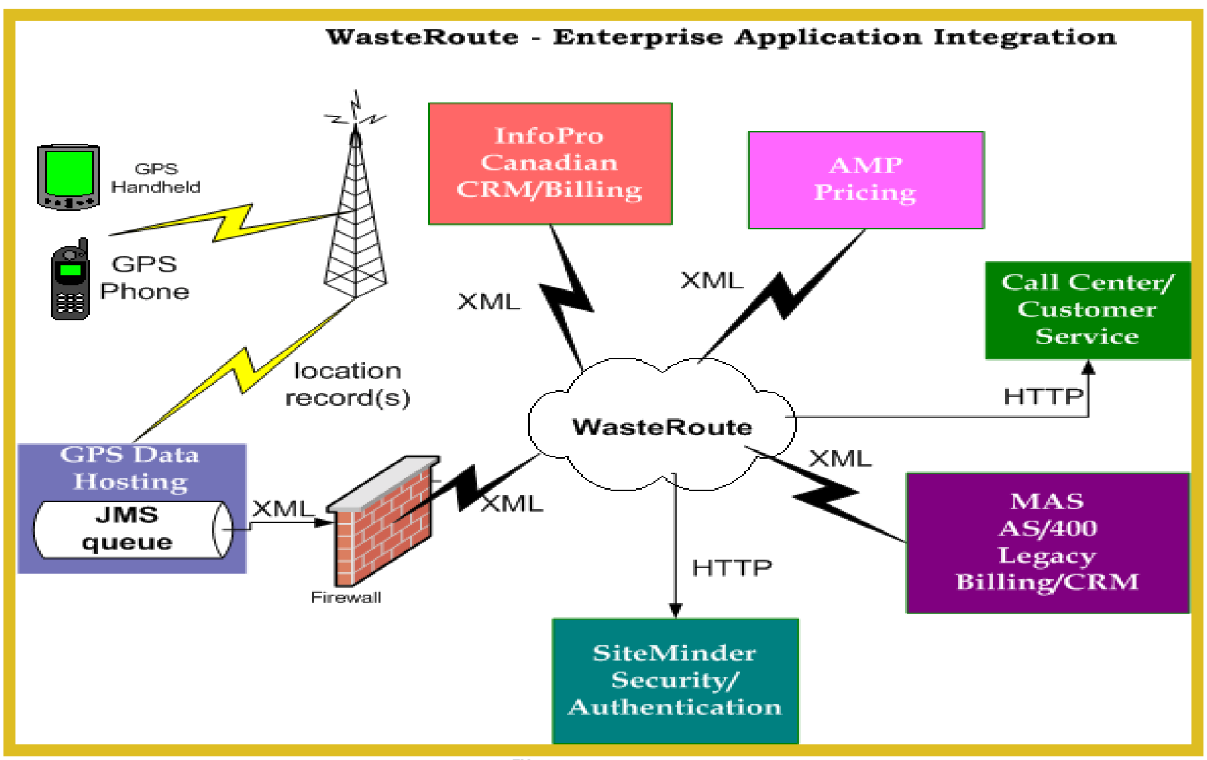

Figure 3: WasteRoute™ Enterprise Application Integration

The applet consists of both tabular data (in forms and reports) and a map displaying customer locations, landfills, and other facilities against a background of streets, landmarks, and other geographical boundaries. The unique coordination of the navigation tree, customer data and interactive map make the application simple to use. Ease of use is very important to WM, as local route managers with a wide range of computer skill sets use the application.

A given customer can have many stops on many days, each of which represents a location where the vehicle stops. A stop may have one or more orders, each of which represents a container in which trash is placed, or a residential home. This representation models the business to support customer service at the container level, but intelligently collapses orders from the same customer into a single stop as appropriate. For example, this permits the optimization engine to view three containers at a strip center, even though they are at different coordinates in the real world along a driveway, as one stop for routing purposes. The model is also sophisticated enough to account for the time required to service additional containers at the same location with configuration parameters. This database is automatically synchronized with the existing AS/400 infrastructure.

Deployment

From the onset, WM understood that deploying an application like WasteRoute™ would fundamentally change the way WM services their customers. Getting people to change for any reason is very difficult, and failing to orchestrate the change risks failure. The initial deployment was designed to have 36, out of 66 market areas, completed in 2003. The first classroom-training class was conducted in March of 2003. To assist training and achieve a larger knowledge base, one resource from a neighboring site participated in the deployment. The objective was to train multiple people simultaneously while gaining on-the-job experience. In retrospect, this design worked very well. By the time the visiting site was set to deploy in April and May, the resources already had several weeks of hands-on experience. The instructor-led training class was broken into two major components: standard operating procedures and application training. Following the initial instructor-led training courses, WM deployed a series of self-paced web-based training courses that covered each of the topics individually. While the exact savings that were experienced varies, one specific example in Elgin, Chicago shows the reduction of one route (from 10 existing route to 9 new routes generated thru WasteRoute™) while also reducing the hours per route by one. The average productivity of the routes has also been increased from 57.06 yards per hour to 63.41 yard per hour. Figure 4 shows the results of this solution.

When software such as WasteRoute™ is deployed across an organization, employees tend to be defensive and resist changing the way they do their job. To maintain morale and build trust between employees and management, WM built a proactive communication plan and included employees at every step during the rollout. The reduction in routes was achieved with the full support of drivers because WM did not have to layoff any drivers. The reduction in employees needed for the remaining routes was accomplished through normal attrition.

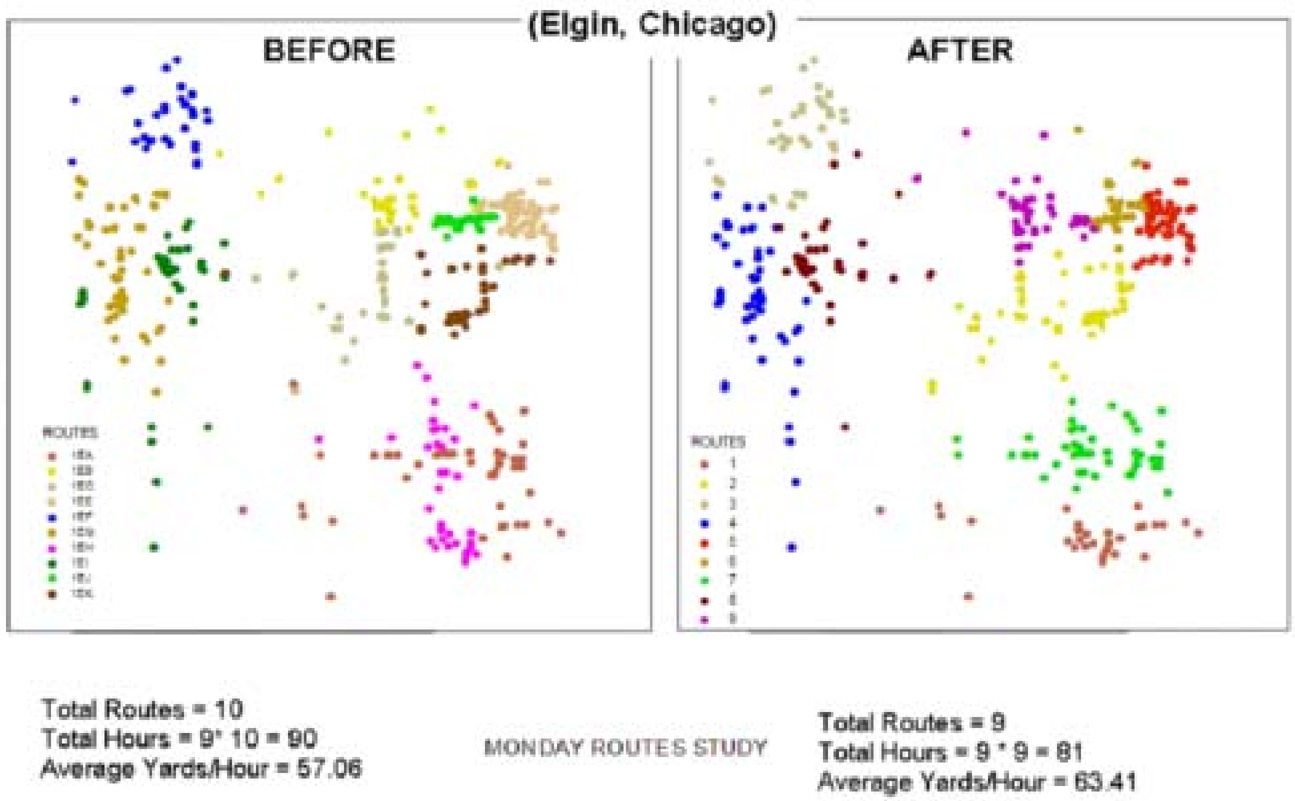

Figure 4: An example of a small site, located in Elgin, Chicago, shows the reduction of one route, which is a 10 % reduction, while also reducing the hours per route by 1 hour.

In Baltimore, Fleet Optimization Manager Renee Huff says, “Driver involvement has been a crucial success factor in implementing WasteRoute™ at our site.” Huff projected WasteRoute™ on a screen and received valuable feedback from drivers on route density and capacity limitations. Giving the drivers ownership in the process resulted in a greater willingness to adopt and improve the overall success.

The deployment for an individual site was broken into four major components: Service Boundary Analysis (SBA), weekly balancing, clustering stops and lastly optimize each daily route. SBA gave the site the opportunity to remove any overlapping territories between neighboring WM sites. Weekly balancing attempts to move customers to different days of service if necessary to balance the workload each day of the week. Included in this step is a review of each customer’s container size and frequency. If a customer has a small container and is serviced three or more times per week, it is advantagious to exchange the container for a larger one and reduce the frequency of service, thus reducing the cost of service for that customer. As you could imagine, this step has the potential to add time to the deployment as each customer that changes days or container sizes, requires a personal phone call by a WM representitive to confirm the change. The clustering step gives the user a first look at the geographies of the routes without creating individual route sequences. The optimization step creates the sequences for each of the daily routes. Following the creation of the routes, driver and management reviews concluded the predeployment steps. Once the driver approved of the new route, a go-live date was set for the site, customer notifications were distributed as necessary via phone calls, mailing or door hangers were appropriate.

Impact and Business Benefits

Why did WM need a route optimization initiative at this time in its revitalization stage? Following a four-year emphasis on growth through acquisitions, the inevitable result was a wide range of business processes for the routing function. WM’s underlying theme for its operations now is to strive towards Operational Excellence. WasteRoute™ was clearly identified by corporate leaders as one of the building blocks to make this happen. In order to sell this program to stakeholders and key personnel, the key objectives and their results were summarized into four integrated components: profitability, safety, customer service, and route optimization:

Profitability

In February 2003, CEO Maurice Myers remarked, “Over the past year, in pilots at 27 different hauling locations, we’ve reduced drivers and trucks by up to 17% and on average 10%. The company operates 15,000 commercial and residential routes – our goal is to achieve the average pilot reduction at 10%. Each route is estimated to cost $120,000 annually so our potential cost savings are meaningful to our bottom line.”

With a graduating deployment schedule, financial benefits increased on a non-linear scale. Cost benefits began to be realized in the second quarter of 2003, with full-year, realized savings at approximately $18 million and costs at roughly $10 million. WM anticipates the savings to come in the long term. As each site becomes more familiar with the software and it becomes institutionalized across WM, additional cost saving will be accounted for. The 2004 cost savings include reductions from all 435 operating depots and is estimated to be $44 million. Additional route reductions and thus cost savings are expected as WasteRoute™ continues to be deployed across WM’s 400+ hauling locations throughout North America in 2004. It became apparent early in the deployment that cost saving was not the only impact WasteRoute™ had. Increased revenue was a direct impact as routes had more capacity, management better understood daily vehicle activities and sales was able to focus on targeted areas to increase route density. WasteRoute™, the application developed upon the optimization engine of IIT, brought these savings within reach.

Customer Service

Stabilization of routes has resulted in more consistent and reliable service for customers due to more effective communication between dispatchers, customer service and drivers. Being able to visualize the location of facilities or the area covered by a route enables a sales agent to make increasingly accurate judgments about which customers to target. It also helps them close deals by offering those customers appropriate pricing options.

Route Optimization

Tom Derieg, VP Fleet Services and Logistics and Executive Sponsor of the WasteRoute™ initiative, states, "This past year was one of patience and persistence for our team members and the many employees around the company who helped us analyze the efficiency of our routes. I am very pleased to report to you that we EXCEEDED the goal Maury Myers set out for us in December 2002 – we were asked to reduce 750 routes and our 2003 cumulative accomplishment was a reduction of 984 routes [goals exceeded quarter over quarter in 2003]. It is tough to admit that we had an efficiency issue but based on our results I am very proud to see how much this work has strengthened the company already." The most significant improvements occurred in the Oregon Market Area where 46 routes were reduced against a goal of 12, and their optimization efforts continue in 2004.

In a short span of four years, WM has transformed itself from a fragmented organization headed in many directions to a centralized corporation with a unified goal of Operational Excellence. The success of WasteRoute™ has brought WM closer to realizing the benefits of its size and scale. This Fortune 100 company is now delivering on its promise of operational excellence and differentiated service as an example to the waste industry. Applying optimization towards the reduction of routes has also made WM receptive to the idea of an increased role for operations research techniques in other operational areas, such as facility location placement and service boundary delineation.

Safety

The net effect of reduced routes continues to improve operational efficiency and increase cost savings for WM, but also delivers a positive impact on the environment and employees. Fewer trucks on the road has resulted in a noticeable reduction of emissions and noise. Reduced travel during busy times of the day, and less traffic for the communities in which WM is a member are also noticeable benefits. Routes must be planned to incorporate company rules that prohibit zigzag and double-siding operations. The WasteRoute™ application ensures users incorporate these company standards while defining parameters for a route optimization.

"Safety and WasteRoute™ are inextricably linked," explained Jim Schultz, VP Safety. "The WasteRoute™ team recognized from the outset their responsibility to employees, customers, and people in the communities we serve to ensure safety is the foundation. Both teams work together to keep 'Mission to Zero' as the 'north star' principle in program development," he added. To do [this], operational safety is a cornerstone element in the WasteRoute™ implementation.

Conclusion

Mergers and acquisitions are often conducted when two organizations can gain business benefits by consolidating shared operations. In 1999, Waste Management acquired businesses at the rate of one per day, so it was imperative that WM search for a way to manage this growth simply to ensure survival. During that same year, WM made an explicit goal of achieving some of these business benefits through route optimization, and, with the help of Institute of Information Technology, realized this goal by delivering WasteRoute™. This GIS-based route management application delivered reduced operational costs by 1) organizing routes to minimize overlap and thereby reduce the number of vehicles required to service customers; and 2) sequencing the stops along a route to make the best use of fuel, driver schedules, and disposal trips. The integrations made to the application allow customer service personnel to quickly resolve any issues related to service by giving representatives relevant information about the customer in a fast, efficient, and easy-to-use manner. Marketing and sales personnel also use WasteRoute™ to offer appropriate pricing to a prospect, or to select a new market area to serve based on existing routes and facility locations.

There is little doubt as to the success of this route optimization initiative, as financial results from the initial deployment of WasteRoute™ are very positive. With the rollout of WasteRoute™ being the most significant effort of 2003-2004, WM will reduce 10% of its collection routes. WasteRoute™ was deployed across the nation beginning March 2003 with a net effect of 984 fewer routes at the end of the year, exceeding their goal of 750, resulting in a savings of $18 million. Estimated over the course of the entire year for 2004, this translates to a savings of $44 million. Since WasteRoute™ is still being deployed to various sites throughout the nation, additional route reductions will add to the savings already being realized.

Authors' Information

Primary Author
Mr. Bob Kraas, MBA, MA
Managing Director
Waste Management, Inc.
First City Tower, 1001 Fannin ST, Houston, TX 77002, US
Phone: 713-265-1494 Email: bkraas@wm.com

Co-Authors
Surya N Sahoo, Ph.D., P.E.
Institute of Information Technology, Inc.
2204 Timberloch Place, The Woodlands, TX 77380, US
Phone: 281-296-2224, Email: surya@e-iit.com

C.V. Ramanakumar, M.S.
Institute of Information Technology, Inc.
2204 Timberloch Place, The Woodlands, TX 77380, US
Phone: 281-296-2224, Email: kumar@e-iit.com

Mansour Raad, M.S.
Institute of Information Technology, Inc.
2204 Timberloch Place, The Woodlands, TX 77380, US
Phone: 281-296-2224, Email: mraad@e-iit.com

Seongbae Kim, Ph.D.
Institute of Information Technology, Inc.
2204 Timberloch Place, The Woodlands, TX 77380, US
Phone: 281-296-2224, Email: skim@e-iit.com

Byung-In Kim, Ph.D.
Institute of Information Technology, Inc.
2204 Timberloch Place, The Woodlands, TX 77380, US
Phone: 281-296-2224, Email: bkim@e-iit.com