Recreating Delivery Routes for a Vendor-Managed Inventory Replenishment Business Model with ArcGIS Online

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Abstract

Delivery businesses usually begin with a small number of customers and delivery stops. Routing of these stops can often be processed by simple city-to-city routes as needed. As a business grows, new customers are added and commonly placed on existing routes or on routes where the timing of inventory supply needs coincide with those of the new customers. A diagnostic analysis was conducted on a case study company to evaluate route efficiency to minimize resource consumption and labor hours. The company selected for study was researched to explore and collect data on route organization, measurement, and overall efficiency. Considerations included business (vendor) supplies, customers' needs by exploring regular stops (once a month), and maintaining supply through those stops. Assessing the existing routing process for efficiency (or lack thereof) was conducted with ArcGIS Online software to examine business logistics and economic benefits. Findings suggest improvements could be made in regards to driving time and mileage driven. This equates to resources saved by reducing expenses on employee work hours and gasoline consumption, notwithstanding improving service to clients.

Introduction

Background

Delivery is a direct or indirect aspect of every business, so new developments in information technologies and software logistics aid the efficiency of the deliveries, which affects the costumer and therefore the business's success (Confessore, Corini, and Stecca, 2008). A delivery company is most harmed by wasteful routing and most benefited by efficient routing. This critical routing task is typically solved through the study of minimization of transportation costs, known as the vehicle routing problem (Confessore *et al*., 2008).

To succeed at business with a service or product delivery method in today's fiercely competitive market, a service or product must be provided in a reliable, effective, and cost-efficient manner (Choudhry and Khan, 2001). The software industry has worked hard to remedy some of the waste that a delivery business endures and to create a more efficient solution than relying on human judgments based on familiarity with the area and roads. There are a number of software companies that have tried to obtain a corner of the software market by providing tools to make business routing as efficient as possible. The number of deliveries, sequencing, and route length are the most important factors that affect cost, so shortening the distance or spending less time en route, without

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diminishing the quality of service, will lower costs (Schruben and Clifton, 1968).

Inventory routing problems arise when a number of customers rely on a supplier to provide them with a given commodity on a regular basis (Bard, Huang, Jaillet, and Dror, 1998).There are many factors that could be addressed when beginning the endeavor of examining the delivery methods of a business. There are major differences in types of delivery businesses and elements within the businesses that are involved in the delivering of the service or good. At each stage, the handling of the order to the fulfillment of the delivery, there is critical need for order and efficiency (Boyer, Prud'homme, and Wenming, 2009).

Evaluating delivery routing methods requires close examination of the key factors, such as the amount of product needed to be delivered, distance needed to travel, employment cost of making the delivery, and resource cost to make deliveries.

Case Study Background

The company selected for study provides services of bottled water: 5-gallon bottles of purified water. As a direct part of the study, the researcher incorporated experience working with the company. In addition, experience was coupled with direct observation of delivery routes, logistics plans, and general workflow. For many years, the company did not utilize vehicle navigation GPS (Global Positioning Systems) such as Garmin and/or TomTom. As a result, from observations and experience, a delivery driver’s best utility and guide was a cell phone and receiving turn-by-turn directions from the customer. MapQuest was also helpful, but not as user-friendly as Google Maps has become. Online directions would be only useful with someone relaying them over a cell phone. Before the company provided cell phones to drivers, if the driver did not have their own personal cell phone, contacting the delivery driver was very difficult in the event an urgent message or a delivery was required and needed to be conveyed to a driver.

Based on records and experience, the company took steps around 2003-2004 to offer cell phones to the delivery drivers to provide a direct means of contact, enabling driver-to-office support. This enabled a greater information-sharing platform to aid in problem-solving and managing daily delivery routes. However, cellular phone communication – while improving direct communication – did not offer an assessment of current route efficiency and routing logistics.

To begin data exploration and diagnosis of business processes, exploratory interviews were conducted with ownership of the company to help further understand the company logistics and to communicate potential benefits of using GIS to explore delivery logistics and improve coordination and profit. General information gleaned from experience and from exploratory interviews helped to shape data needs as well as an understanding of how delivery routes within the study area were initially shaped.

Study Area

The study area consisted of the depot service area, which includes the location where all delivery routes depart from and return to. The depot and service area shared a geographic location centralized in and around the city of La Crosse, Wisconsin. Within the study area, there are routes covering geographic areas including the three states of Minnesota, Wisconsin, and Iowa. The area covered by these routes was developed by determining limits to the company's ability to effectively supply the customer's inventory. If an account arose that was too small or too far away, the account would have been naturally declined by the business due to not being cost beneficial and thereby opposed to the company's main goal of fiscal profits. Figure 1 illustrates the served counties containing the delivery routes.

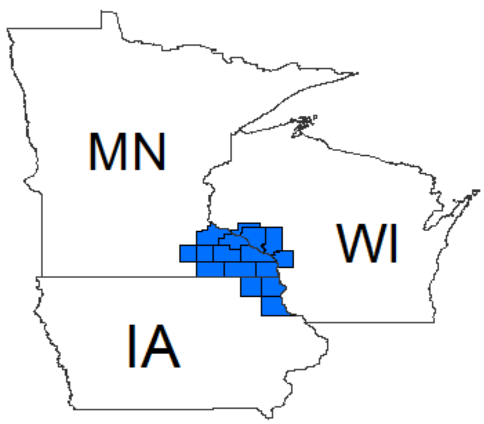

Figure 1. The study delivery area, with 16 affected counties in blue. The combined area of these counties is approximately 10,000 square miles.

The current delivery area could be expanded for future customer markets and delivery expansion. In addition, goals of the study were to promote suggestions to change, modify, or augment existing markets if changes could be realized to generate a profit and be viewed as efficiently maximizing productivity in the number of deliveries made along with increasing the amount of product sold on a daily basis. After initial exploratory discussions with management, the company was supportive of recommendations to revisit and scope new target areas or alter delivery routes in the study area depending on what was discovered from the findings.

Methods

Methods involved acquiring and expanding a knowledge base to learn about delivery challenges and problems. This was important to define as it served as a metric to address and evaluate after the design and implementation were completed.

Initial interviews with the business owners and managers were held to obtain data and inquire about the current delivery concerns. After obtaining the list of the delivery routes and customer addresses, the information was standardized (by clarifying a standard address as building number, road, city, state, and zip code) and manually entered into an Excel spreadsheet with the pertinent categories being account number, street address, city, state, zip code, and current route. Delivery stops (customer addresses) and each route's information were entered into Microsoft Excel and subsequently converted into a csv (comma delimited) file, which was then imported into Esri’s ArcMap 10 for digital point location data. The locations for business stops (clients/customers) were then geocoded with the World Geocode Service.

Generating data sets to assess the eight delivery routes involved the process of separating them from the master spreadsheet and adding them into the ArcGIS Online interface, individually. The use of ArcGIS Online is an appealing one, as the interface is simplified by limiting options, which is not necessarily desirable to someone very familiar with the Esri product line including ArcMap, but ArcGIS Online eliminates the difficulties of building a network and adhering to the sometimes arduous constructs necessary to utilize a more involved network analysis.

Therefore, ArcGIS Online was selected, as network associations were already constructed and built to adapt to the workflow this study required. ArcGIS Online was also selected for use as a means of aiding in the communication of findings from the study. The case study company may also decide that using such a software platform may be an important means to revisit routing studies in the future.

After adding the delivery stops for the current routes, a depot file was loaded. The depot file contained the address of the business in La Crosse, Wisconsin, which is the start and end point for all of the delivery routes. The program helped to calculate the best time for a driver to start the deliveries to effectively make all of the required stops on a given route on a given day. The results generated normally would have been a great help to the delivery drivers, as they were not expected to make the delivery stops in any particular order, but rather to simply stop in whichever order seemed best from their experience until they ran out of supply or until they made all the deliveries. Given this output, the drivers would have received a very reliable sequence to most effectively use their working time and also travel the least amount of delivery distance.

Figure 2 provides an example of parameters used for the calculations. It was natural to set all routes to start and end at the depot. The start time for the route does not impact this analysis. For one route, the vehicle parameter was set to one, but when eight different routes are desired, the number for analysis was changed to a maximum of eight, accordingly. For maximum stops, the value was almost always set higher than the expected desired number of stops on most routes. Figure 2 was the example used after delivery stops were known for a specific route. The delivery stops were sequenced for that specific route as the number of delivery vehicles was limited to one and the delivery stops variable was made to contain all the stops. Figure 3 is a result of Figure 2 analysis, which would result in only one delivery route, thereby routing all stops in sequenced delivery order.

Usually, if the analysis were limited by the program, the routes would have limited the number of stops according to the total route time.

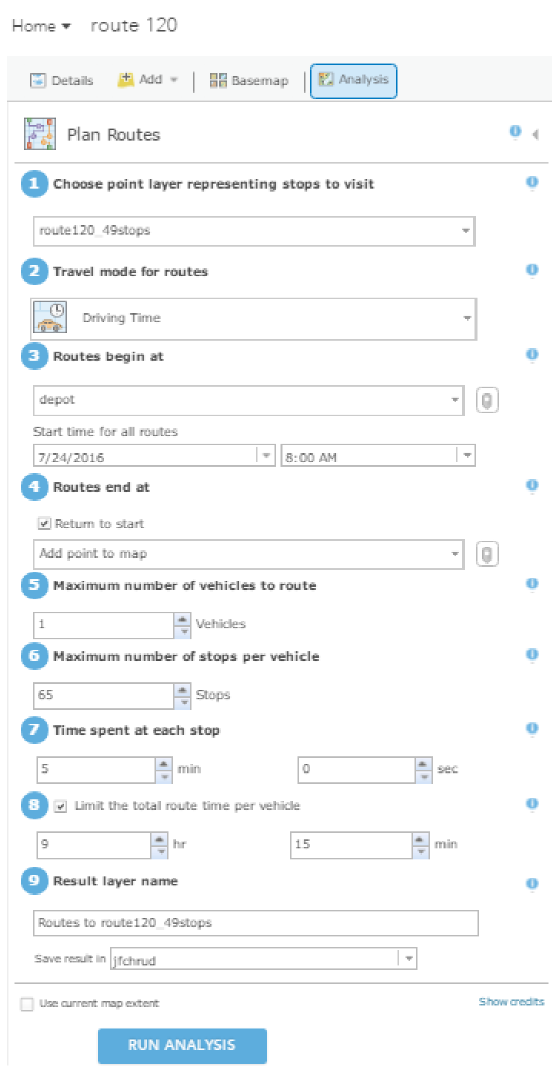

Figure 2. An example of the parameters set for routing analysis.

The total route time was calculated as the travel time plus additional time of five minutes for each stop. The total route time was limited to nine hours and fifteen minutes, since the delivery drivers are not limited to eight-hour work days but also are not paid overtime for working more than eight hours in a day, so minimal overtime was expected and included. After all the current routes were sequenced, it was possible to quantify the mileage and drive time as a standard to compare final results. Results of these eight routes were compiled and are represented in Figure 4.

Figure 3. Sample route that resulted from the analysis example shown in Figure 2. This route is about 190 miles starting on the south end of the image going north and then southwest to the city of Winona and ultimately back to the depot, which is also the starting point. Along with the 190 miles, the driver would need to stop at 48 addresses, get out of their delivery truck, and make contact with the customer.

The major limitation that had to be addressed was the fact that ArcGIS Online would only accept a maximum of 250 stops, where the total stops for this study was just short of 350. To get around this limitation, it was necessary to decrease the master dataset down to 250, which was done by eliminating 100 stops from the data set, which were stops in cities that were represented by other stops in close proximity. For the purposes of the study, the 100 delivery stops were temporarily removed to adjust for the limitation of the software.

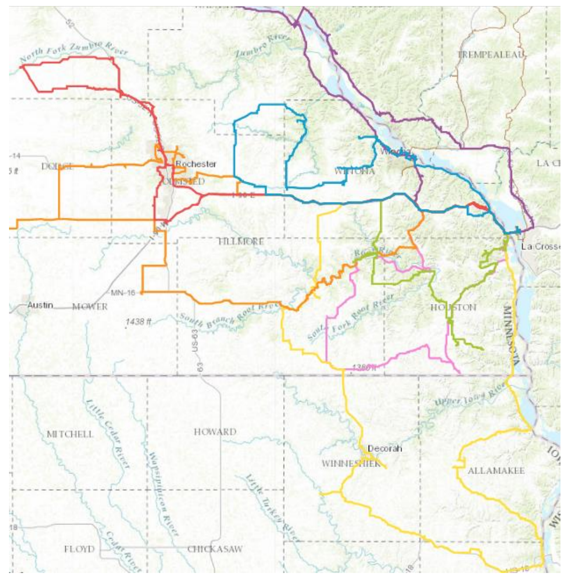

Figure 4. The current eight routes each with a discrete color. There are eight different routes shown. This is how the current routes would look if the delivery drivers made deliveries in the order which ArcGIS Online recommend as shortest distance to travel to complete the route. At this point, no new routes were made but only sequenced according to logistical efficiency.

With the 250 stops that ArcGIS Online allowed to be added to the map (interface), it was then able to create eight new routes. To work around the 250-stop limit, it was necessary to split the eight routes into two groups of four. The 100 stops previously eliminated from the initial data set were then added to these data sets based on proximity to the route. The data sets were then reevaluated to produce four routes each. This was an inconvenient additional step, but a solution to the 250-stop limitation.

The original routes only had one route into Iowa (yellow route on Figure 4). This was one route that needed updating with the new routes, as the stop locations and time of the route was simply too much. Software generated new modeled routes with two routes going into Iowa (purple and blue) (Figure 5).

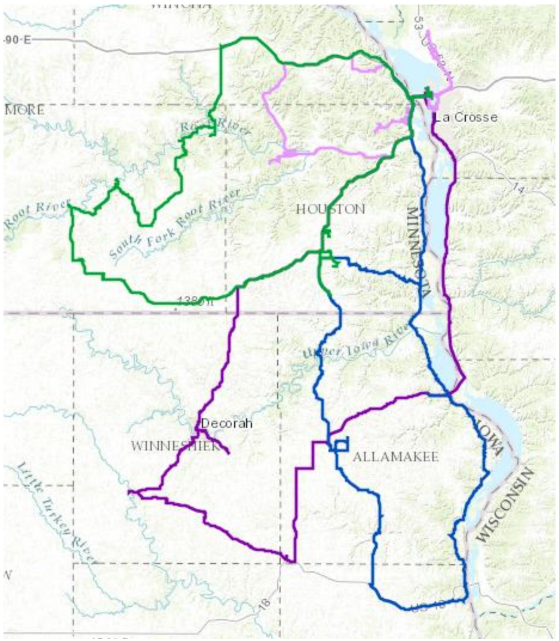

Figure 5. The first four new routes. The different colors represent four distinct daily delivery routes. This graphic shows half of the delivery routes (four) and approximately half of the square mile area of the delivery area. This area is approximately 5,000 square miles. The four colors are used to express four distinct delivery routes.

Limitations

Before comparison is made between the old route mileage total and the new route mileage total for the sake of evaluating the cost benefit of switching to new routes, there are several limitations the new routes faced that the old routes did not address. The fact that ArcGIS Online only allowed for 250 addresses (delivery stops) limited the ability to rely wholly on the software to create the eight new routes without manipulation of the parameters in the analysis/plan route tool. It was necessary to create two sets of four routes, which was much more work and created two resulting sets of data independent of each other, which must have affected the final results.

Figure 5 (above) shows the first four routes with two Iowa routes. Figure 6 shows the second set of four routes, and Figure 7 is simply the combination of both sets of routes together. The significance of the impact is not known, but it must be noted that human interference impacted the end results, and it can be deduced that the process of eliminating delivery stops and then adding them again as a way around the software's limitations would have only decreased the overall effectiveness of the study to, at the very least, a small degree.

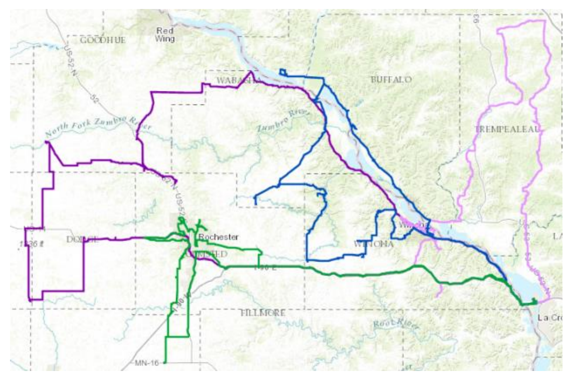

Figure 6. The second four new routes. The other half of the total delivery area is represented here.

The current Iowa route became too large and unmanageable by one delivery route; if the Iowa stops were to be completed in one route, it would take a total delivery time of over 12 hours and use more supply then the current delivery vehicles could hold. This presented a problem for the business, which was highlighted in this study, as the old Iowa route was far too impractical for time and distance. If the newly calculated routes were not constrained to the 9 hour 15 minute time frame, it would have been possible to decrease overall time by making larger routes. This larger route limitation can be seen by comparing Figure 4 with Figure 5, as two routes into Iowa are necessary because of the time constraints.

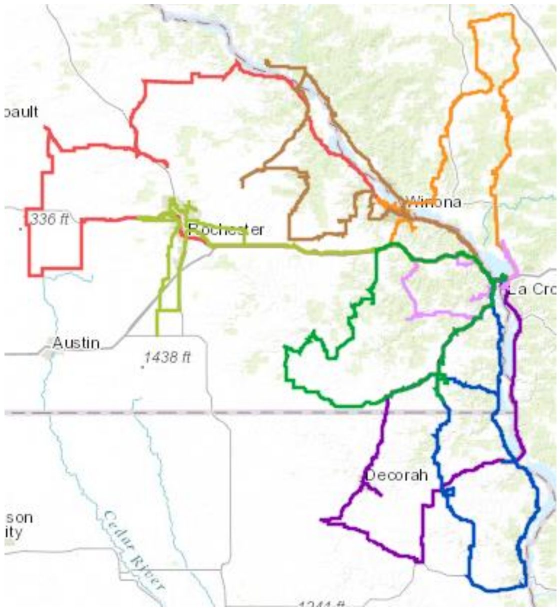

Figure 7. The eight new routes, each with a discrete color. This figure is the combination of Figures 5 and 6.

Results

Evaluating routes on the summative output of mileage and time driven resulted in new routes to decrease mileage as well as drive time when compared to the old routes (Figure 8). This metric is the most telling, as it is what can be seen as the greatest mark of the business bottom line. Specifically, lower mileage on company vehicles means lower cost on vehicle maintenance and gasoline purchases. Lower miles traveled often means less delivery time, and that delivery time means lower cost towards an employee's hours reported for wages. If route time is less than the maximum allowed time, additional accounts could be added in the future to maximize route profits.

To add to this study, and for the purpose of comparing the new routes and the company's original routes, it seemed worthwhile to evaluate how large an impact would be made if the new routes had only one Iowa route. As such, a comparison was made using the measure of delivery time and total miles driven. Eight new routes were created with the software, making sure that only one Iowa route existed, which was accomplished by raising the limit on the number of stops per delivery route and the delivery time limits. It was still necessary to work around the delivery stop limit within the software to create these routes in two separate processes. Figure 9 shows a map of the new routes created with only one Iowa route, which can be used for visual comparison with Figure 7 and Figure 4 as well as the chart in Figure 10.

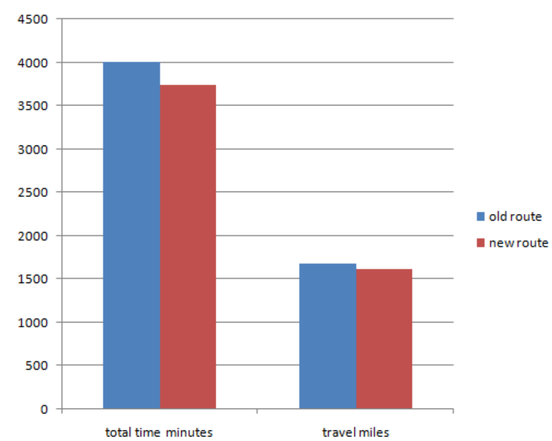

Figure 8. Chart showing the cumulative travel time and cumulative miles of new routes, with two routes going to Iowa. The new routes will be lower in overall time needed to complete delivery routes and lower in overall distances travelled.

Results from this comparison are interesting, as the benefit of only having to drive the distance to Iowa once instead of twice did not produce the magnitude of benefit that would be expected by reducing one of the longest distances. These new results appear to show that the total travel miles of the new routes with

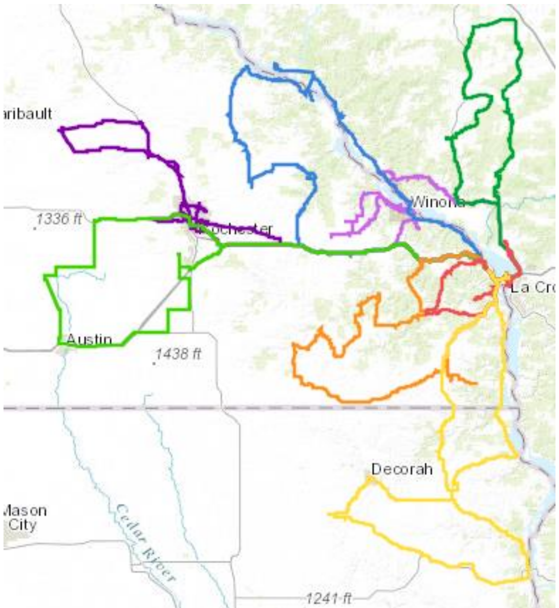

Figure 9. New routes created with only one route (yellow) going from the depot in La Crosse, WI to Iowa.

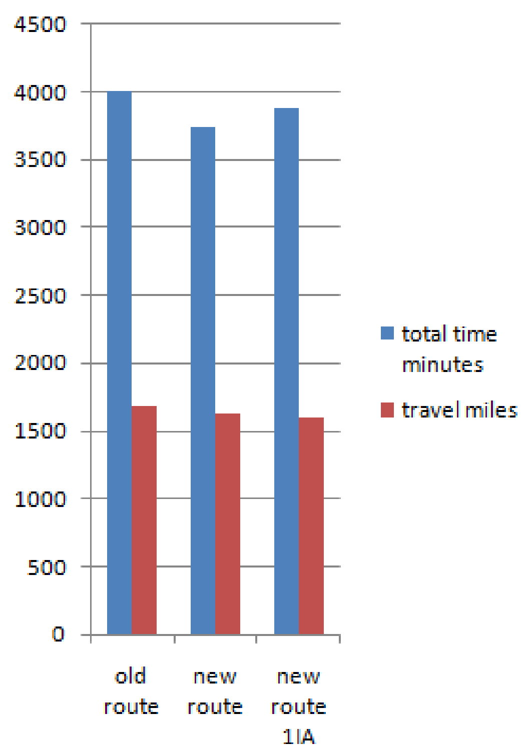

Figure 10. Chart showing total cumulative time and distance travelled for old routes and the two sets of new routes generated with either one day of deliveries to Iowa labeled "new route 1IA in the graph" or two routes travelling into Iowa, which is labeled "new route."

one Iowa delivery route is less than the new routes with two Iowa delivery routes; however, the routes where there is only one delivery to Iowa shows an increase in total travel time minutes. A big change can be seen when comparing maps of the new routes with one Iowa stop compared to the new routes with two Iowa stops, which is the routing of the deliveries in the furthest west portion of the study area near Rochester, MN. When the Iowa routes changed from two back to one, the other routes also changed from six back to seven; the additional route the software created did not create a substantial overall reduction in miles and time traveled. The other routes, when changed to seven from six, utilized the extra route to create a more balanced approach towards delivery stops and to utilize drivers on those seven routes without creating a large decrease in travel miles. Balancing routes makes it easier for drivers to complete routes in the designated time while focusing on reduction in miles. The most probable reason why the new single route into Iowa resulted in greater time but less miles may be differences in posted speed limits as well as travel on secondary roads, where travel time on those roads is greater despite miles being lower.

Discussion

The next step in this study would be to express and implement changes realized herein and then evaluate how changes made a difference for business logistics through a longitudinal study. Data could then be extracted for a time series comparison using the price of gasoline to explore cost savings or other future predictions. Additionally, hourly rate employees and service to customers may be tracked and compared to new route implementation.

To emphasize savings, the quantitative amounts could then be compared over greater periods of time. Implementing changes for the current routes and deliveries could be a difficult task as changing a pattern will affect employees and customers. If changes are made, this becomes a change in business logistics and perhaps even an organizational change. As such, communication would be necessary to inform employees and customers of new changes and the benefits it will bring to them.

Conclusion

After reviewing the benefits of this study, it leaves opportunities to explore how much more effective Network Analyst, in Esri's ArcMap suite, would have been as the tool for this analysis. Network Analyst does not have the 250 limit of delivery stops, which was required to be worked around, as this study was accomplished in ArcGIS Online. ArcGIS Online offers a much more user-friendly interface so it is easier to use by less proficient users of ArcMap or those not specifically trained in higher-order software.

Given the limitations and problems that were addressed, this work helps to remedy and offer alternative solutions for common dysfunctions found in many business logistical systems involving delivery and routing. These changes could be implemented without major changes to any driver’s route. The fact the software helped to re-sequence older routes to more current routes are a benefit to the company. Not only were potential solutions to current route problems explored, but business managers may use this information to justify changing routes, adding or decreasing employees, expanding service areas, and assisting current customers.

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