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ESRI K–12 Solutions: School Bus Routing—Using ESRI Tools to Address the Problems

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ESRI K–12 Solutions: School Bus Routing—Using ESRI Tools to Address the Problems

An ESRI White Paper

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Introduction

Transportation directors at school districts all over the country are faced with problems that are making the day-to-day process of transporting students to school difficult. Among these problems are

- Budget cuts
- Rising fuel costs
- Difficulties in hiring qualified drivers or office personnel

Additionally, laws are being passed that affect the way schoolchildren are transported and even where bus stops can be placed. Parents, administrators, and school boards are demanding more accountability and better service from drivers and transportation officials. There are tools and utilities available to help increase the efficiency of the transportation office and the drivers that are driving the routes. This white paper will address using ESRI® tools to solve some of these issues.

The Problem

Students

Key to the problem of student transportation is the students themselves. Student movement is always an issue, and while some districts may have stable student numbers, other districts have highly mobile student populations. Accounting for where your students are in relation to bus stops and school boundaries is key to creating a good transportation system. In addition to just demographic movement, grade progression also affects busing; each year, students change schools, bus stops, and ridership as they progress through the school system. Data accuracy problems also are a constant issue, and getting the correct addresses for a student database that is in constant change is always a challenge.

Stops

Bus stop locations are another piece of data that is constant changing. As students move, change grades, or just stop riding the bus because they now have a driver's license, bus stops may need to be moved, added, or deleted. The stop that was created last year to accommodate the new kindergarten student may not be necessary this year as that student has moved on to first grade. Safety considerations also come into play with the location of bus stops; knowing if a stop location requires a bus to make a right-hand turn for a pickup or requires students to cross the street is critical in making decisions on stop locations.

Buses

The number of available vehicles, capacity, equipment, and maintenance schedules affect every fleet that makes deliveries and pickups. In school transit, however, they become critical in nature. If the vehicle is underutilized, then costs go up, the public impression is bad, and efficiency is minimal. If there is not enough capacity, then you risk the danger of not getting kids to school or being in a hazardous or even libelous situation by overloading a bus. As noted in the students' section, knowing where the students are and

how many will be at a particular stop directly impacts the number of buses needed for each district and school.

Hazards

There are many different hazards that play a role in school bus routing; these hazards are both man-made and natural. Man-made hazards, such as road construction, and natural hazards, such as flooding or fire, can greatly affect the daily routes. Some hazards can be planned for, and some must be dealt with in real time as they become problems for drivers on the road. Increasingly, transportation offices are being asked to consider man-made hazards as well as sexual predator locations or violent crime in relation to bus stops and routes.

Drivers

For most school districts, hiring and retaining drivers have long been a challenge. The split shifts, early mornings, and irregular hours make it difficult to find drivers that are willing to stay long term. In addition, providing benefits for part-time drivers is difficult and in some cases impossible. Training for drivers is expensive and ongoing. New laws make even the hiring process expensive, requiring criminal or background checks. Certainly the ability to retain trained drivers long term that you can count on affects your ability to provide a good, stable service. Drivers calling in sick or just not showing up for work necessitates using as few buses as possible to handle the daily workload.

Creating a Solution

This section explores different ESRI technologies and how they can be applied to various routing problems that most school transportation offices face every day. In most cases, the solution will involve a combination of ESRI technologies along with some object models to do data processing.

Special Education Routing

With the 9.3 release of ArcLogistics™, the components and functionality necessary to do special education routing exist in an off-the-shelf product. Special education routing within school districts requires curb-to-curb routing, which means picking the students up and dropping them off at their home locations. Using specialties or custom capacities, ArcLogistics can be configured to take into account, for example, a vehicle that has spaces for wheelchairs as well as seats for ambulatory riders. Specialties also can be set up for vehicles that have aids, oxygen tanks, or other necessary items for special education transportation (figure 1).

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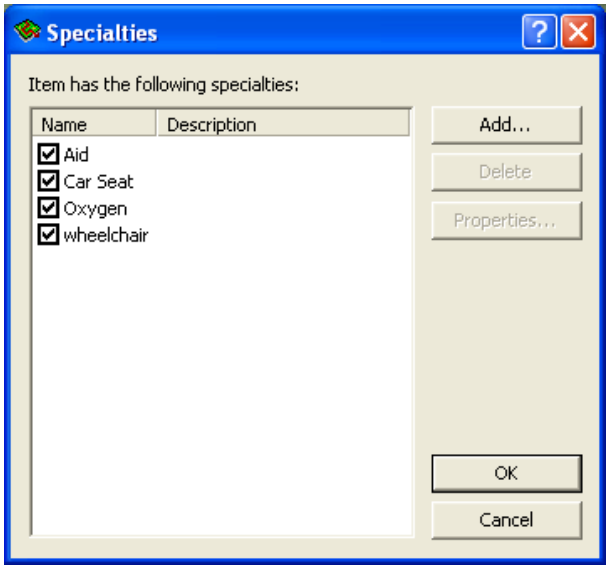
Figure 1
ArcLogistics Specialties Window



Although there are many ways to configure ArcLogistics for use in special education, the trip request functionality (figure 2) of ArcLogistics provides maximum flexibility in routing; it allows pickup and delivery locations to be different. Time windows can be set, and the volume and specialties information mentioned previously can be used for special education. Maximum flexibility in time windows and routing parameters should always be used to get the best solution (figure 3). More information on using ArcLogistics for special needs can be found at www.esri.com/paratransit.

Figure 2
ArcLogistics New Trip Request Window

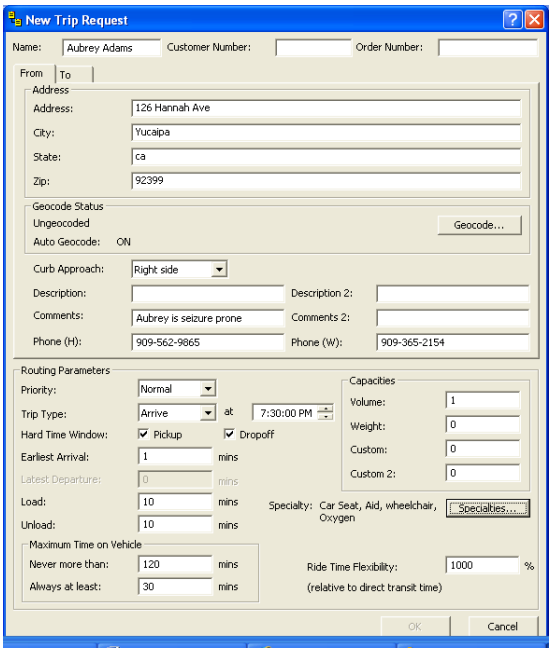
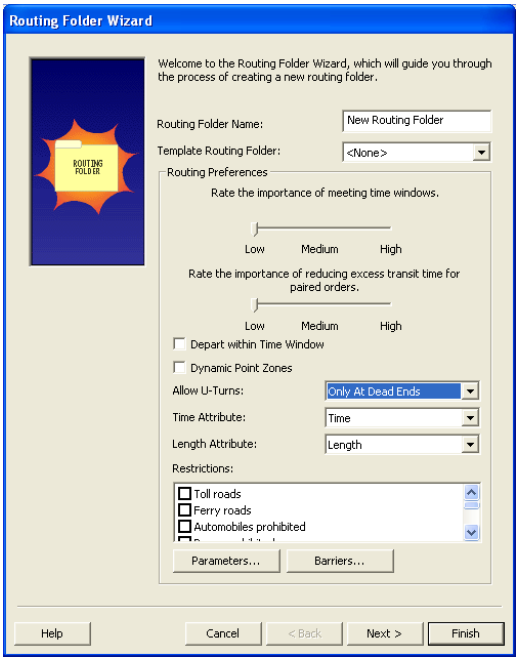


Figure 3
ArcLogistics Routing Folder Setup



Assigning Students to Stops

The process of assigning students to existing bus stops can be done in ArcGIS® using ArcGIS Desktop and ArcGIS Network Analyst tools. For this process to work properly, all the students and bus stops need to be completely geocoded. The quality of the data will determine the accuracy of the results. To assign students to bus stops, you will need a geodatabase containing streets with a network dataset, students, and stops. In addition, you can use boundaries and/or walk zones so that only students inside the school boundary but outside the walk zone will get assigned. ArcGIS Network Analyst uses a network dataset to find the closest facility (bus stop). There are instructions on creating a network dataset at www.esri.com/networkdataset.

The best method to execute the student-to-stop assignment process would be to create a model or a Python script. Creating a model helps automate the system so the user only needs to set the correct parameters, and the model processes the request. A model diagram is included in this white paper.

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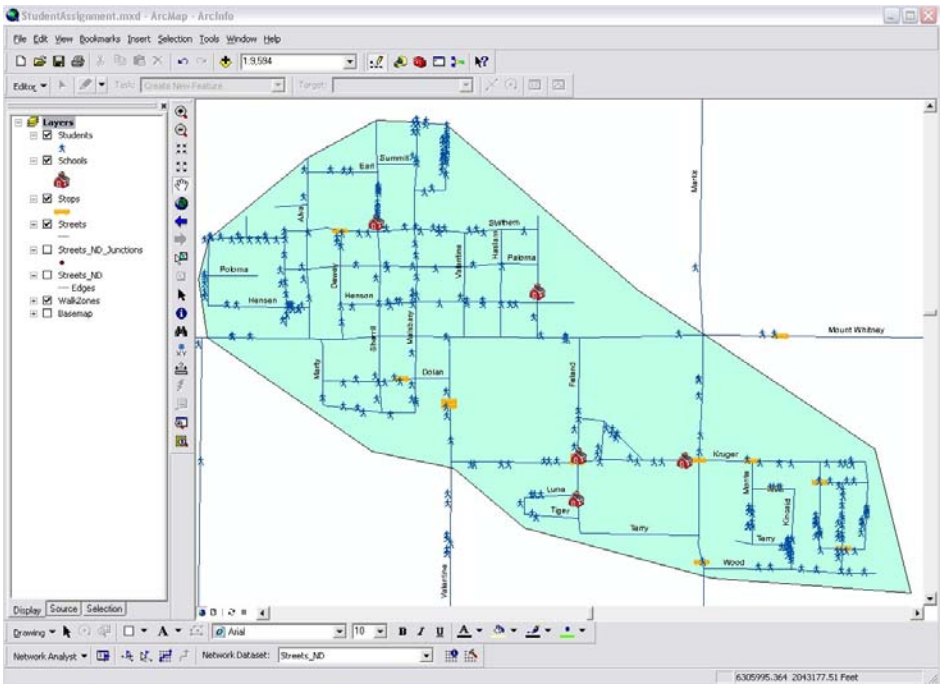
- **Begin with a map document that includes students; stops; streets with a network dataset; and, optionally, walk zones and boundaries** (figure 4). Walk zones can be created using the Network Analyst Service Area tool. The Service Area tool will calculate the walk zone based on the parameters you set for distance or time. When creating the service area, you can set up barriers to create hazard zones within the walk zone area.

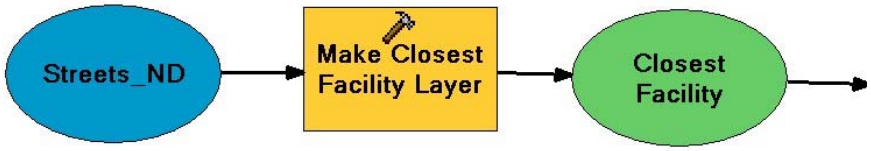
Figure 4
ArcGIS with Data for Assigning Students



Walk zones and boundaries can also be digitized if the Network Analyst Service Area tool doesn't meet your needs. If you have existing walk zones and/or boundary polygons, they can also be used.

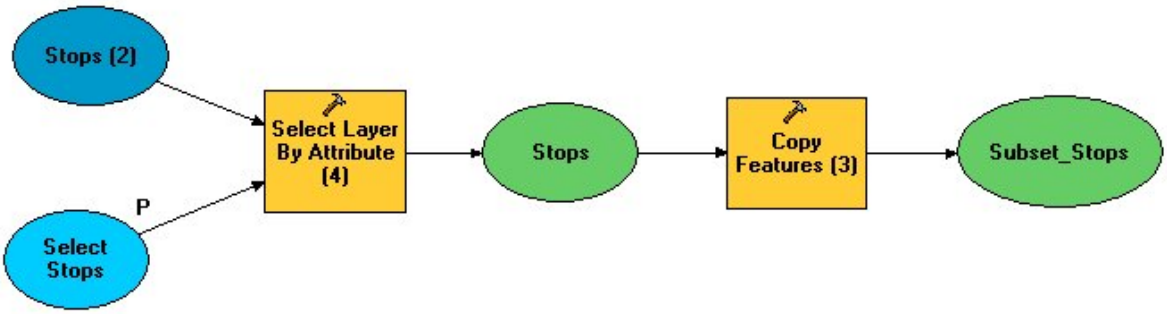
- **Use the Make Closest Facility Layer tool from the Network Analyst tools.** This tool is used to load students and stops; when solved, the tool uses the network dataset to find the closest stop to the student based on rules you set (figure 5).

Figure 5
Object Model Diagram from ArcGIS



- **Select stops to load as facilities.** If each school's group of stops is in a separate feature class, then this step will be skipped; however, most often all the stops are maintained in one feature class. After selecting the stops to use, load the facilities into the previously created Closest Facility layer (figure 6).

Figure 6
Object Model Diagram from ArcGIS



- **Select students to load as incidents.** If using walk zones, the selection should include a Select By Location tool to find the students in the walk zone and use the Calculate Field tool to calculate "Walk" in the attribute table indicating that they are assigned to walk. This can be done prior to creating the model or it can be set as part of the model. In this step, you can also use the Select Layer By Location tool to select only the students inside the boundary and exclude those outside the boundary. You may also have hazard zones as polygons inside the walk zones that you can use to include the students that should get assigned to a stop. An example of using a hazard zone would be for students who live within the walk zone but in an unsafe area for walking to school (figure 7).

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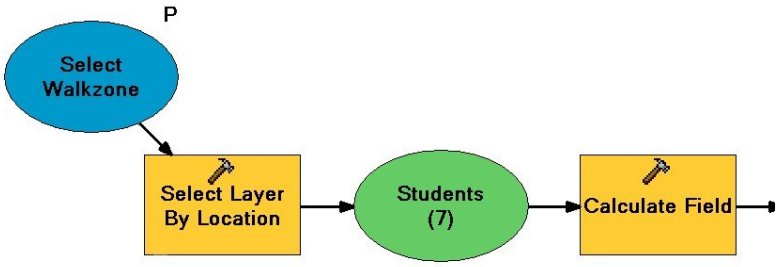
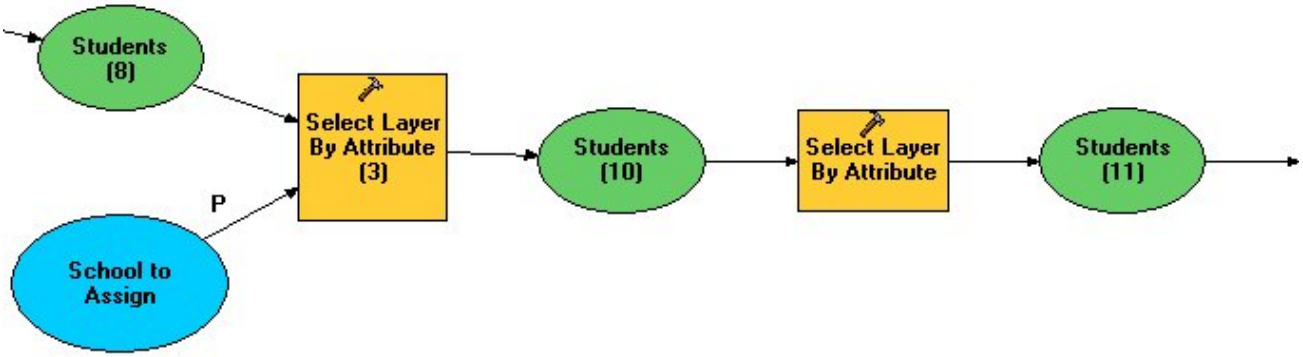
Figure 7
Object Model Diagram from ArcGIS



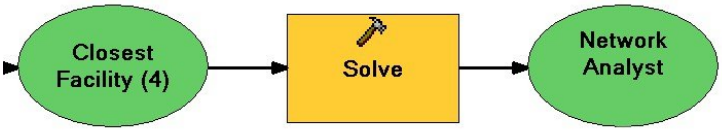
- **Load the selected incidents (students) into the previously created Closest Facility layer** (figure 8).

Figure 8
Object Model Diagram from ArcGIS



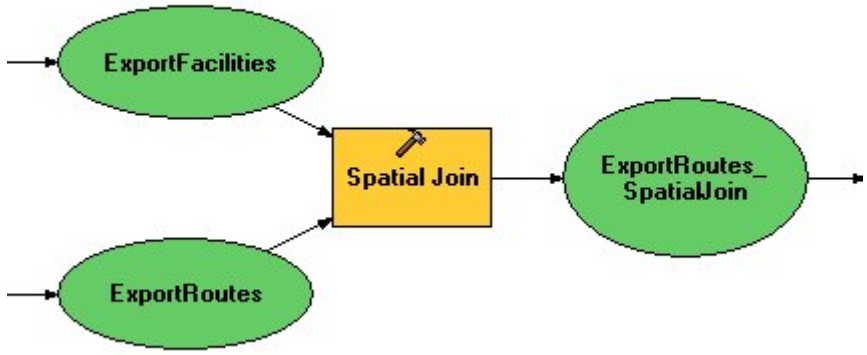
- **Use the Network Analyst Solve tool.** This tool will solve finding the closest facilities (stops) for all the students that were previously loaded in the Closest Facility layer (figure 9).

Figure 9
Object Model Diagram from ArcGIS



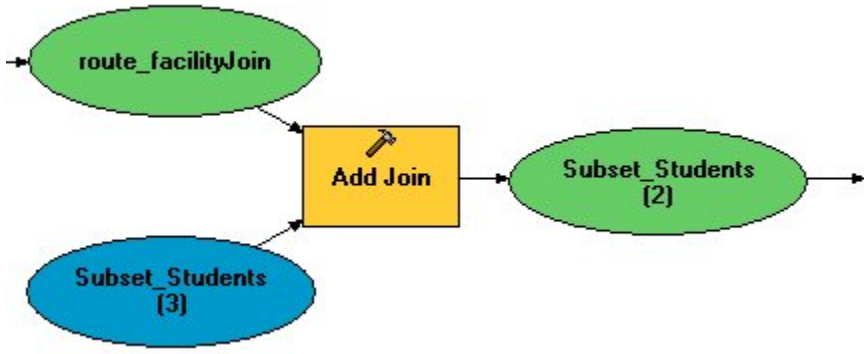
- **Create a spatial join between routes and facilities on the Closest Facility layer.** This step (figure 10), along with the following steps, will help get the stop description distance and volume into the student and stop attribute tables.

Figure 10
Object Model Diagram from ArcGIS



- **Join the route-facility join to the students attribute table** (figure 11).

Figure 11
Object Model Diagram from ArcGIS



- **Use the Summary Statistics tool with the students and the route-facility join.** This step will get a load count of students assigned to each stop.

- **Join the statistics output to the students, then use the Calculate Field tool to calculate the volume field in the stops table with the count field in the stats join table** (figure 12).

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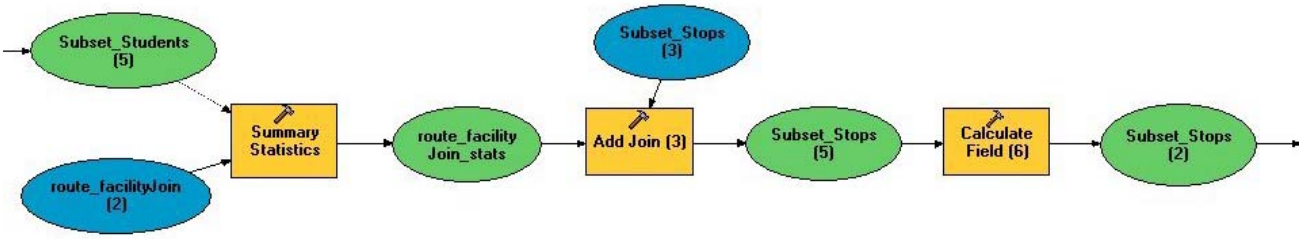
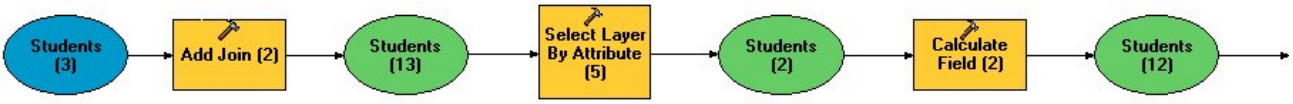
Figure 12
Object Model Diagram from ArcGIS



- **Use the Calculate Field tool.** This step will calculate the stop description, stop distance (optional), and the assign field into the students attribute table by joining the students with the route-facility join (figure 13).

Figure 13
Object Model Diagram from ArcGIS



If you have all your students in one table and all your stops in one table, you will want to create subsets (shown in this model) during the process or set a definition query for the school you are working on before starting the assignment process. This needs to be done because of the way the students and stops are given their facilityID and incidentID in the Make Closest Facility layer.

Regular Education Routing

ArcLogistics works well for regular education routing if you have the volume (number of students at each stop) in the database when it is loaded into ArcLogistics. This can be accomplished through the procedure described above in assigning students to stops. The resulting data can then be imported into ArcLogistics, and using the standard ArcLogistics routing tools, a solution can be created. Depending on your particular workflow or district policies, routing can be done with any of the three variations of routing, trip requests, paired orders, or single orders done as pickup (going home at the end of the day) or delivery (going to school in the morning). For single-tier routing, the pickup/delivery method works well and processing time is relatively short. This method would be done as follows.

1. Create your bus barn and your schools as locations, and make the time windows appropriate for the times you want your buses at those locations. For example, the bus barn may be open and available for buses from 4:00 a.m. to 6:00 p.m., and that is appropriate. But, you may only want your buses at the elementary school between 7:45 a.m. and 8:00 a.m., so you would set the Time Window accordingly (figure 14).

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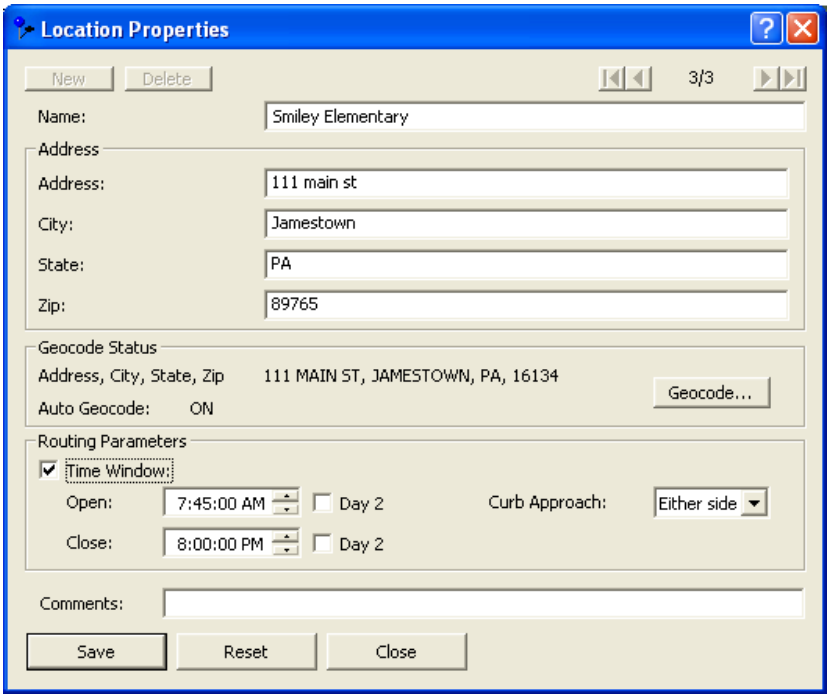
Figure 14
Location Properties



2. When setting up your schedules, be sure to allow enough time at the beginning location to do vehicle inspections or other things that drivers may need to do prior to beginning their runs (figure 15). If the bus is departing one school to start another run at another school, your Time at Start may allow only a few minutes or you may provide no time at all.

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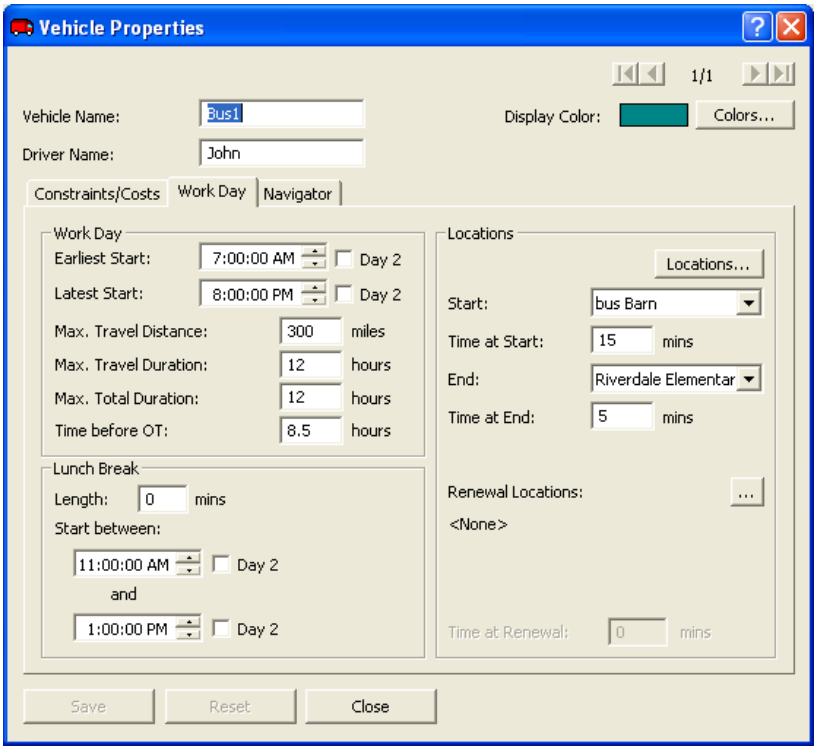
Figure 15
Vehicle Properties



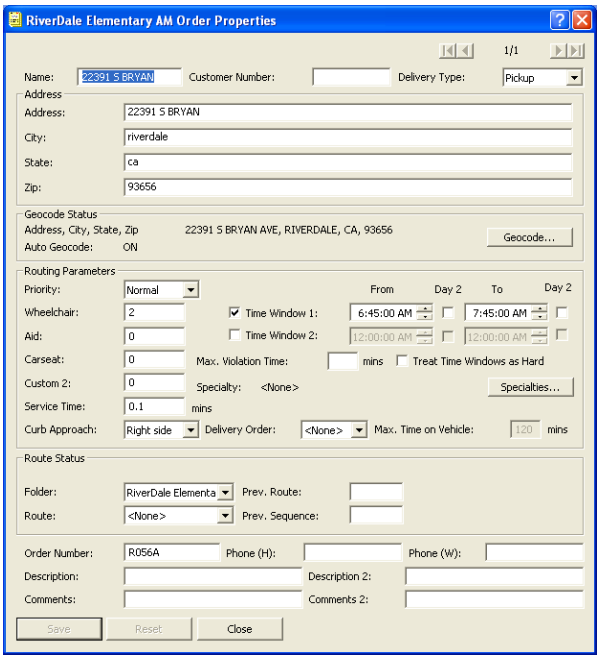
3. Setting the time windows on your stop locations is key to making the route work properly. They must be set after the time the driver leaves the beginning location and prior to the time the driver arrives at the first location (figure 16). Additionally, the time windows should be set for not more than your maximum allowable ride time. So, the example for a morning run to school would look something like the following:

   a. The bus barn (location 1) is open from 7:00 a.m. to 8:00 p.m. I allow 15 minutes for my drivers to check in and do their vehicle inspections (figure 16).

   b. I want all students (delivery orders) picked up between 6:45 a.m. and 7:45 a.m. (figure 16).

   c. I want all buses to arrive at the school (location 2) between 7:45 a.m. and 8:00 a.m. (figure 14).

Figure 16
Order Properties



Routes can be solved one school at a time, or you could solve multiple school routes if you use the zones or specialties functions to identify which buses should serve which school. For multiple-tier routing, the same process could be followed. You could then create a plug-in that would move the individual runs to a single vehicle. Solving the problem globally is possible, but particular attention must be paid to the time windows at each school and the stops. ArcLogistics will always look for the most efficient solution for routing (figure 17). Having time windows that allow buses to make multiple drop-offs at a school may create solutions that are not practical for school bus routing.

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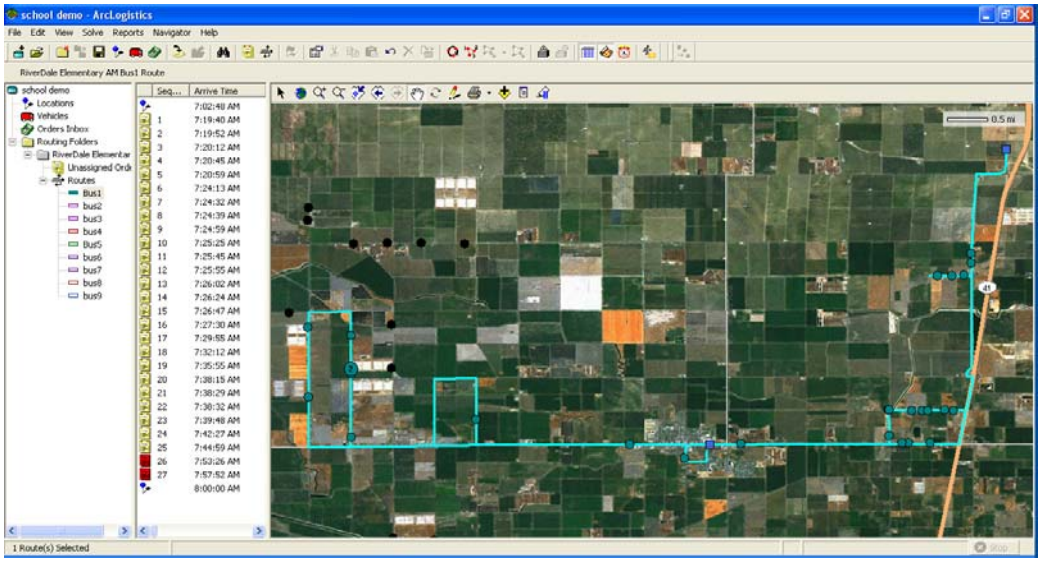
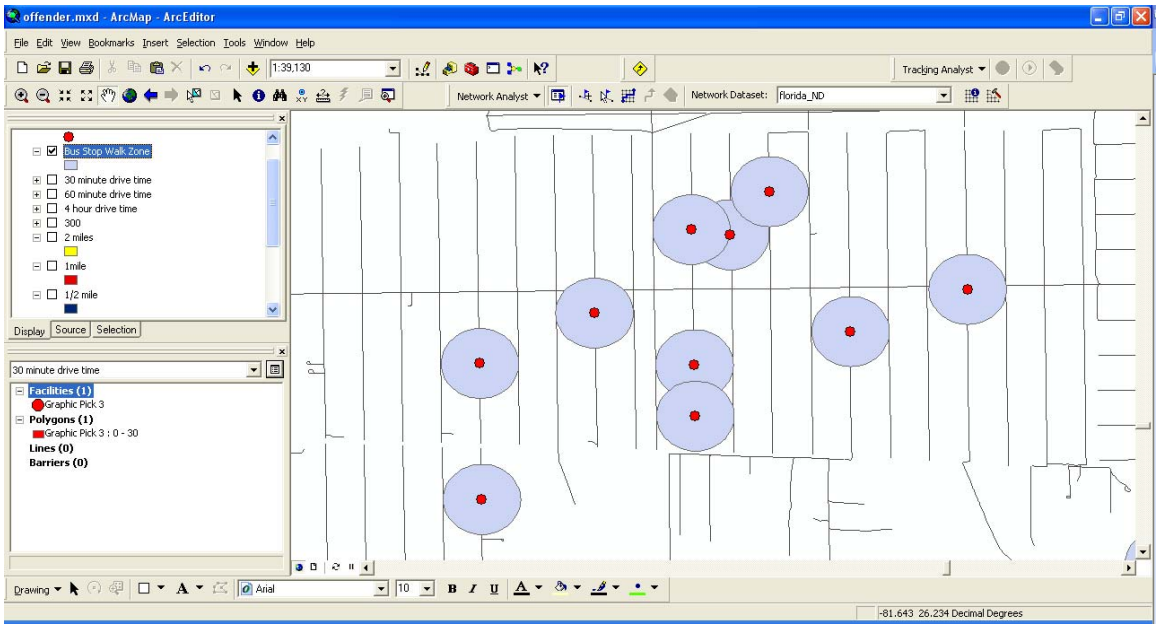
Figure 17
ArcLogistics Map View



Optimizing Bus Stops

There are several ways of optimizing or checking your bus stops to see if they serve the student population optimally. You should always use caution and physically check stop locations to ensure the safety of a stop. One method is to use a simple buffer tool around student locations to see if a student falls within a specified distance of the district walk-to-stop policy. For example, if the district has a .25-mile walk-to-stop policy, you could create a .25-mile buffer around each student. Any stop that falls outside these areas would be unnecessary and could be eliminated, thereby saving time and money. By the same token, any student that did not have a stop within that buffer would be out of the walk policy, and a stop should be created that would be close enough for the student to walk to (figure 18). The buffer method would use a crow's flight or straight-line distance for the calculation, but the same results could be achieved using the find closest facility function in Network Analyst. This would give you the actual street path distance.

Figure 18
Quarter-Mile Buffer around Students



Sexual Predator or Other Analysis

Florida's Designated Public School Bus Stop Law (SB120):

> *As of 10-1-2004 this law will prohibit schools from placing school bus stops near certain registered sex offender [RSO] residences (and move any that currently are near certain RSOs), -AND- prohibits certain sex offenders from living within 1,000 feet of -Designated Public School- bus stop.*

School transportation offices are being subjected to more restrictions all the time. They are required to do additional analysis and research to determine what a safe stop is, where bus stops can be located, and which students should be transported. ArcGIS and Network Analyst can help answer many of these questions (figure 19).

In addition to answering these questions, school transportation offices are being held more accountable for the occurrence of incidents. If a child does not show up at home, what happened to them; where did they get off the bus; did they ever get on; and if someone else picked them up, how far away can they travel (figure 21). ESRI tools can help answer these questions. The ability to look at information spatially and get the results of queries is invaluable in ensuring the overall safety and security of students and the transportation operation. When you can visually view the transportation operation and the locations of incidents, such as accidents over a five-year time period, you can save time, money, and possibly lives.

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Figure 19
Sexual Predator Locations within a One-Mile Buffer

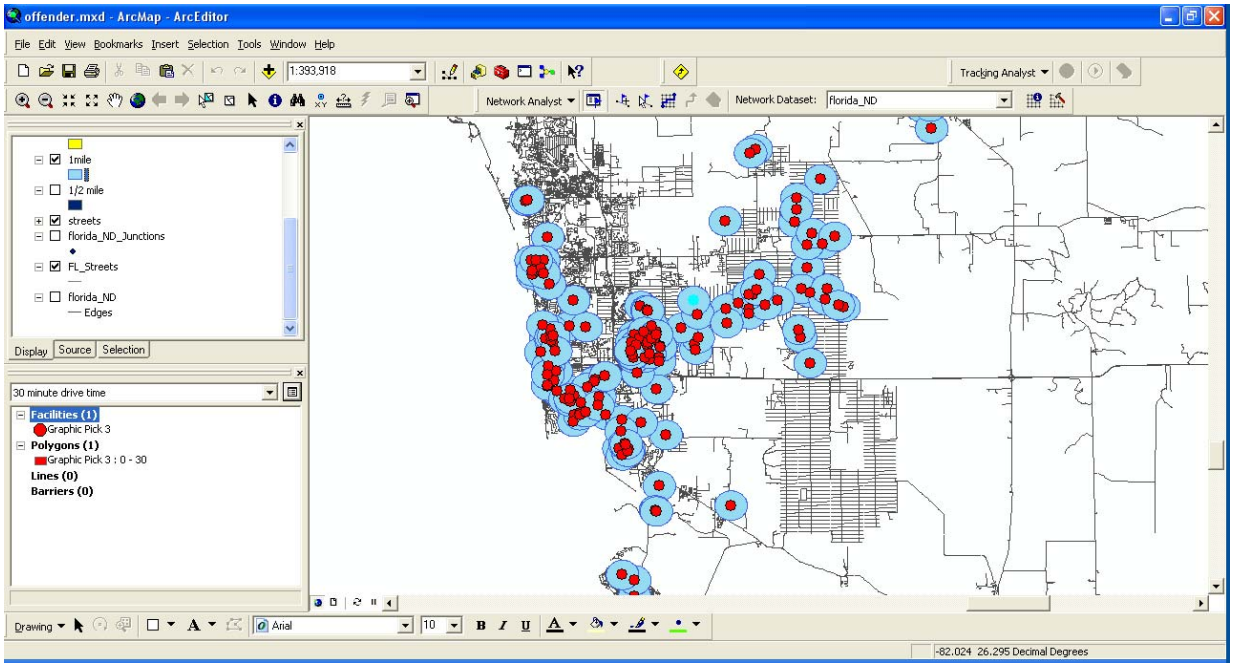
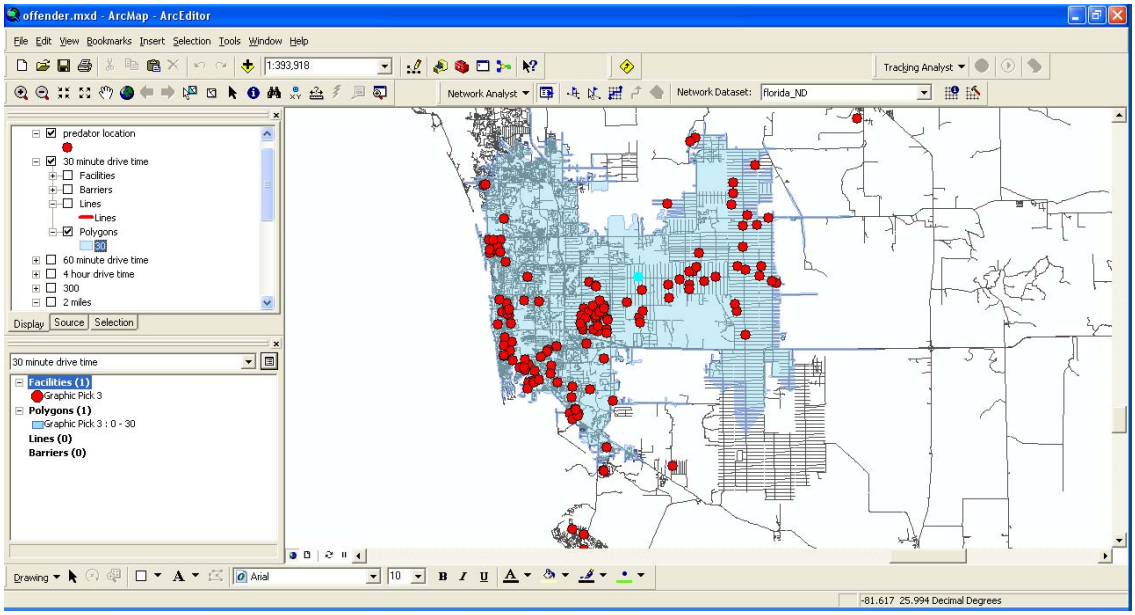


Figure 20
Travel Distance from a Known Address

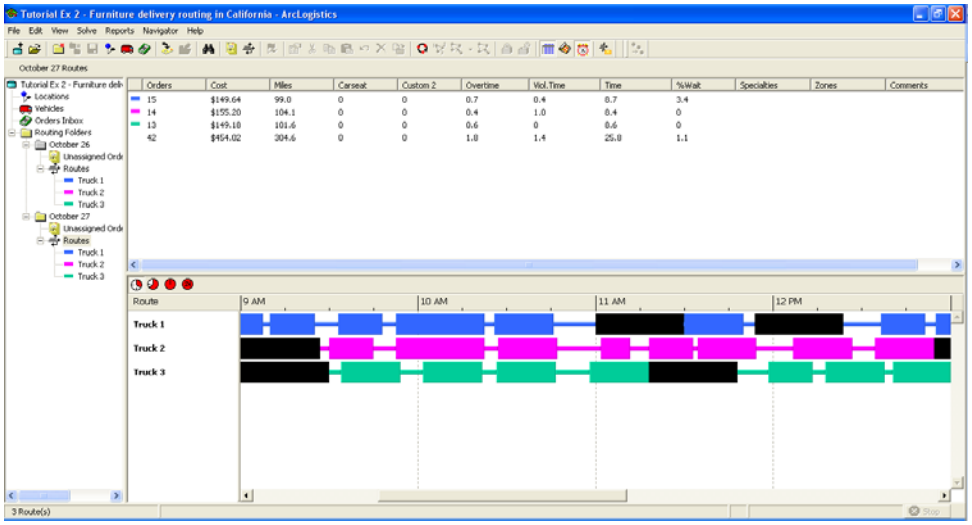


Field Trip Routing

ArcLogistics will not only create field trip routes and schedules for drivers, but its time window also allows dispatchers to see which vehicles are available at any given time

throughout the day. Additionally, since ArcLogistics calculates all the costs for each vehicle and each run, getting the cost accounting information for your field trips is an easy process (figure 21). ArcLogistics will take into consideration fixed costs, cost per mile, and even driver overtime costs and provide reports that a transportation director can easily access.

Figure 21
Vehicle Costs by Vehicle



Integration

ESRI tools have the ability to read directly from many different data sources. ArcLogistics specifically has the ability to import data from the most commonly used data formats such as .txt, Excel®, Visual FoxPro®, and Access® (figure 22). This ability, along with the data mapping feature that allows you to match your particular data fields to the ArcLogistics data fields, means your data can come from almost any source (figure 23). Once you have set up your import process and mapped the proper fields, this data can be saved as a profile, making future imports quick and easy.

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Figure 22
Data File Import Screen

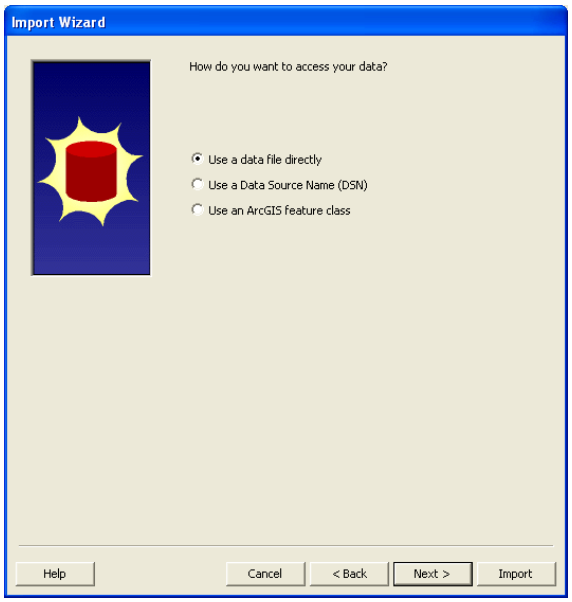
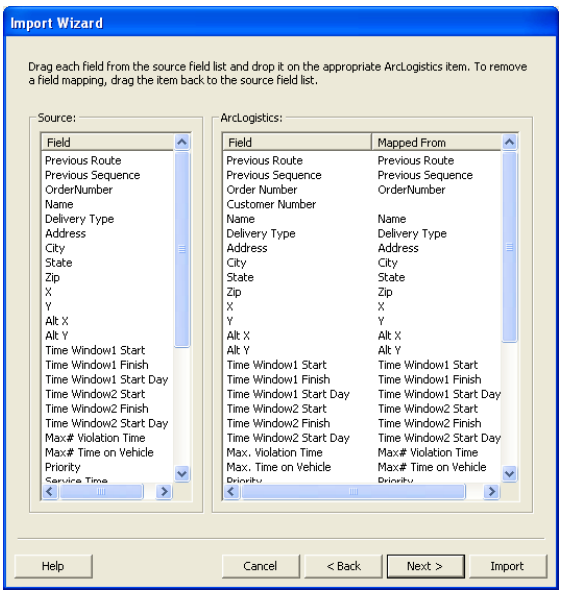


Figure 23
Data Mapping from Import Wizard



If you are using ArcGIS for other analysis, there are many ways to get the data into the system. For more information on data interoperability and getting data into ESRI tools, visit www.esri.com/interoperability.

Information Dissemination

Having the best dispatchers, the best software, and the best plan is of little value unless you can communicate that plan to the people that need the information. A few of the people that need the route information from the system are

- Drivers (route maps, student lists, driver directions)
- District personnel (principals, school secretaries, teachers)
- State department personnel (mileage, ridership)
- Public (where does my student get on the bus, when will they be home, what school do they attend)

All ESRI software has the ability to print reports, and the routing software can provide maps and driver directions for the routing products. Drivers can be handed a map of the route they must drive that day along with turn-by-turn directions. Mileage, cost reports, and summaries can all be provided in report format for those who need the information.

It is more expedient, however, to provide information electronically; this saves time, saves money, and is often safer—for drivers who are trying to follow a route. ESRI tools provide many different ways to disseminate the information electronically to the people that need it. Listed below are a few of the tools and brief descriptions.

ArcExplorer and ArcGIS Explorer

ArcExplorer™ and ArcGIS Explorer are free applications that can be downloaded from the ESRI Web site. These applications allow viewing of the data created from your GIS application. If you have created routes using ArcLogistics, for example, you would be able to save them to a network shared drive, and district personnel using the routes would

be allowed to access and view them but not to modify or change them. www.esri.com/arcgisexplorer

ArcGIS Server

ArcGIS Server allows people to build their own Web-based applications. A district could build its own application that would be accessible to district personnel or others that need the information. An ArcGIS Server application could also allow people to enter or modify the information, providing a feedback avenue for transportation personnel to collect information from the district or even the public. www.esri.com/arcgisserver

ArcLogistics Navigator

ArcLogistics Navigator is an in-vehicle navigation application that provides audible turn-by-turn directions to a driver. It can run on Win32® or Windows Mobile® platforms. Once routes have been created in ArcLogistics, they can be sent to the vehicle for the driver to follow. This eliminates the possibility of the driver losing the printed map and provides additional safety advantages by keeping the driver from having to read a map while driving. ArcLogistics Navigator will always reroute the driver to the planned route if a turn is missed. In addition, the driver can receive any information that is contained in ArcLogistics such as specific information concerning the special education student's needs or a list of students that get on the bus at a particular stop. www.esri.com/navigator

Conclusion

Routing is a complex problem with many variables. While it is difficult, it is not impossible. People have been solving routing problems for many years with little more than a paper map, some pins, and string.

Solving problems in this manner, though, is getting more and more difficult if not impossible; the demands that are being placed on the modern-day dispatcher and transportation supervisor increase daily. The problems are more complex with an almost infinite number of variables. Student transportation, in particular, has become problematic even for the smallest districts. Even the best of solutions that saves the most money often has to be justified to the parent, superintendent, or school board that wants to know why a stop was or was not put in a particular location or why the bus travels down a certain road.

ESRI software can help solve these problems, not only by creating the plan that will pick up the students and save time and money but also by providing the answers to the people that need them.

About ESRI

For four decades, ESRI has been helping people make better decisions through management and analysis of geographic information. Our culturally diverse staff work with our business partners and hundreds of thousands of people who use GIS to make a difference in our world.

A full-service GIS company, ESRI offers support for implementing GIS technology from the desktop to enterprise-wide servers, online services, and mobile devices. GIS solutions are flexible and customizable to meet the needs of all our users.

Our Focus

At ESRI, we focus on promoting the value of GIS and its applications throughout the world and pay close attention to our users' needs. Our software development and services respond to our customers with products that are easy to use, flexible, and integrated. Our technology is multidisciplinary, productive, and valuable to our users.

We have a strong commitment to educating our customers through ESRI's various training programs. ESRI is a socially conscious business and invests heavily in issues regarding education, conservation, sustainable development, and humanitarian affairs.

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