

Harris County Toll Road Authority Maintenance Dispatch Application

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Background/Introduction

My capstone project involved the design, development, and implementation of an application focused on improving assignments and procedures for the Dispatch and Maintenance teams of the Harris County Toll Road Authority (HCTRA). HCTRA is a county run agency located in Houston, TX and supports 125 miles of roadway. On an average day, HCTRA toll roads will see over one million transactions. Due to the number of miles and a steady flow of traffic, it is extremely important that the Maintenance team can stay on top of repairs or issues. To keep such a busy roadway safe, the team strives to improve efficiency wherever they can.

The project focused on helping the Dispatch Team and the Maintenance Field Inspectors use a more efficient way to keep track of problems on the toll road. This included improvements in the data reporting, sharing, and storage of incidents reported to the dispatch team and the jobs assigned to the maintenance crew. The original workflow for creating a work assignment involved the inspectors calling the dispatch team and reporting a problem with a quick description of an issue and an approximate location. The dispatch team then wrote down notes on paper, drafted an email, made phone calls, and then texted work assignments to the inspectors and contractors. After all these notifications, they recorded the assignments into a Microsoft Access database. There was no automation, so everything was done manually, and there were no standards for emails or reporting. More importantly, there was no geographic data being recorded, and nothing could be viewed spatially. Information could only be reviewed in spreadsheets.

The team knew their process was outdated and with 20 Field Inspectors to take care of the entire toll road system, they needed to lean on GIS technology for a solution. While reading articles to better understand how other organizations have used GIS to help with asset management, I came across a white page from the National Cooperative Highway Research Program titled "Capitalizing on GIS and Asset Management". This article focuses on transportation asset management, which was perfect for my project. The introduction of the article discussed the benefits of using GIS for transportation asset management such as how it saves time and money for an organization. It listed topics like increasing efficiency, automation of data collection and mapping, and managing work scheduling. This was helpful because I was able to categorize HCTRA's problems with similar examples given in the article and helped me justify developing this application for my organization.

The article then went on to list 5 different opportunities in which GIS can help with asset management. I found 3 of the 5 opportunities were relevant to the application I had in mind. My plan was to focus on "Manage and Track Work", "Understand the State of the Assets", and "Identify Needs and Work Candidates". Each page talked about the GIS capabilities, value added, and an example from a Department of Transportation. These pages gave me innovative ideas and jumping off points to develop the deliverable goals for this project. By implementing GIS software into the dispatch assignments and incident recordings, the HCTRA Roadway Maintenance teams would have the ability to report and assign incidents faster and accurately. They would have the ability to record the same data as before, but also gain the ability to visualize the assignments on a map and see their status.

Literature Review

The project needed to focus on creating an all-encompassing application for HCTRA's Maintenance Dispatch Team to use when reporting roadway incidents and tracking their status. The idea was to create a one-stop shop for the Dispatch team instead of opening multiple applications in different windows. After reviewing articles focused on collecting GIS data for asset management, successful applications involved multiple software components to capture the data and then to display it. This meant that mobile software would be used to easily collect the data in the field, and desktop software was used to view and edit from the office.

While researching methods on recording data in the field, I found that there seemed to be a trend in using Field Maps and Survey123 when collecting data for events because they were developed to easily record data (Adams and Nowak). They can be developed to enter data with dropdown menus or select items from a list rather than typing. Although there are Esri applications and Solutions created for the specific purposes of assessing assets in the field, Adams explained that not all scenarios could fit into one mold. I agreed with his assessment and believed that this was the case with my organization as well. When I started looking into applications, I found Esri had an application called Workforce designed to assign jobs and track their progress. However, it wasn't very customizable and didn't fit the specific needs of our organization.

I still liked the workflow of Workforce, so I decided to take the approach of Adams and Nowak and combine multiple applications into one solution to make my data inputs fit the needs of our organization. I also researched Survey123's capabilities and how it could be used to build a unique form with customized questions. After reading the Esri article "XLM Form Essentials", it was clear that a lot could be done to customize the Survey123 experience for the user without having to write code. This would solve the problem of fulfilling our organization's need for customization. Halfawy and Figueroa's paper on asset management supported this trend of using XLM Forms in Survey123 rather than writing field calculations or Arcade expressions in Field Maps.

Although the bulk of that project was dedicated to developing a workflow to capture data, being able to display that data clearly and efficiently was a main objective. An article in ArcNews, written by Coray Davis, explained the importance of a Dashboard and provided an example of how it was used to show pavement evaluations, which could be shown to residents of Cary, NC. The information for that project was not made public, but managers and dispatchers were able to view the status of assignments and see charts and lists that displayed priority events. These methods were discussed in Norra's article "Build a Better Dashboard," which I used after assessing the team's needs. The advantage of a dashboard is that a manager can quickly check on an assignment or see the overall status of the toll system without having to make several phone calls or check emails. All the data could be quickly looked up on the computer screen.

All this data being collected had to be properly stored in a database on site and accessible to the GIS department. Previously, the data was stored in Microsoft Access and had no geographic data attached. If data is stored in the same SDE database, multiple organizations could have access to it and do their own reports or analysis. In an example from Anderson's article on recording road traffic incident data, she mentioned how it was used by local police and larger organizations to study problematic areas. This was because when they set up their database they focused on the idea of sharing and connecting the data they captured. A database also allows other applications outside of Esri to access the data. Chivite and Mann both talked about different types of automation. Chivite's presentation focused on connecting Survey123 into Power Automate to send email alerts as surveys were completed. This type of automation cuts down on response times. Originally, the Dispatch team manually typed up each email assignment. Mann's article spoke more on automation of information coming from the field via sensors or monitoring devices. Both are viable options to incorporate into this project because automatic alerts could cut down on response times and help eliminate errors. At this time, the County does not have this infrastructure set up, but it would be an option to further develop the application once these devices are installed.

For any project, detailed planning is key for success. Scheduling meetings with teams, creating budgets, timelines, and risk management. Croswell's book on GIS Project management goes into detail on each of these project management skills. The executive guide "Capitalizing on GIS and Asset Management" that the NCHRP published reinforced these ideas and focused on GIS as it related to transportation. The article highlighted subjects like data and hardware standards, data management, training, and software implementation. I used the high-level ideas from the paper and referenced Croswell's book for more information. These publications helped me establish a plan to implement my project successfully by outlining how to set up meetings with the right people and how to get their feedback efficiently. Croswell's book discussed methods of organizing meetings and how to set deadlines for project check points.

Methods and Analysis

Since this project focused on the Harris County Toll Road, all data was sourced from the HCTRA organization and its employees. Assignment data represented as point feature classes were created by personnel in the field and as well as the office. Some data is in the form of attributes and other types of feature classes.

The HCTRA GIS team already had all the tollway assets mapped out as feature classes, so they did not need to be created. These feature classes consist of polygons, point and polyline features digitized by various GIS team members. The assignments are represented as point features that are created using Esri software that includes ArcPro and online applications like Web Maps, and Field Maps. Survey123 is used to add attribute information to these point feature classes. Dashboards, and Experience builder are used to display information and visualize the different assignments and their locations. There are specific

pages in the experience builder app to view the dashboard as well as a page to create points on a web map of the system map and to fill out a Survey123 form to the right of the map. The web map was created separately and then connected to the Experience builder page. The map and survey page allow the user to create a point on the map and then fill out the survey in the column next to the map. The Survey123 form is linked to each point so when the be user clicks on an assignment point the survey will load in the window on the same page as the map. All of this gives the user the convenience of going to one place to view and edit data.

The Survey123 questions were developed based on the information previously recorded in Microsoft Access. For all current assignments in Access, there was significant formatting and preparation to convert older assignments into points and filling out the attributes.

All the data is stored on the GIS team's production SDE database as a feature and map service. This is because all the current feature classes that represent the assets are already stored in this SDE database, so it makes sense to store the dispatch assignment points there as well. Once a map containing the assignment points was created and all attribute fields were added, the feature was published to a server through an enterprise geodatabase connection where it could be brought into a web map by using the REST service URL created when the feature was published. This URL allows the web map to reference the feature on the server. The benefits to this is that all edits are updated in real time, as opposed to a hosed feature layer and the data can be connected to other applications.

Data Sources

As described in the methods section, the application was built in Esri's Experience Builder (Esri 1) and includes Dashboard (Esri 2), Web Maps from ArcGIS Online (Esri 3) , Survey123(Esri 4). Field Maps (Esri 5) were included so the application can be used in the office or in the field. The assignment dataset was built and then published using ArcPro (Esri 6) and Field Maps Designer (Esri 7) was used to format the attributes for assignments and limit initial information collected because Survey123 (Esri 4) is designed to be the main data entry source. By combining different software, the team now has the flexibility to create reports on a desktop computer via Experience Builder (Esri 1) or any mobile device that supports

the Field Maps app (Esri 5). HCTRA initially creates all features in ArcPro (Esri 6) and then publishes to SQL SDE database (HCTRA 8). Then, feature layers are created using the REST service URLs from the published services on ArcGIS Online (Esri 3). For the Dispatch/Maintenance team to accurately reference an issue location, multiple feature layers that the HCTRA GIS team are used in the Dispatch Assignments Map (Argento 9). The default base map is the Esri Topographic Map (Esri 10). The previously created features include Illumination, Overhead Signs, Sign Structures, electrical buildings called HUBs, Facility Buildings, Pump and Lift Stations, Toll Booths, Tolling Facilities, Bridges, Mowing areas, and Roadway Sections (HCTRA 11-22). As you can see, there are many assets to manage so this application will help the team visualize the entire system on a map. Figure 1 shows a zoomed in area of the toll road that gives a visual of how the assets are represented.

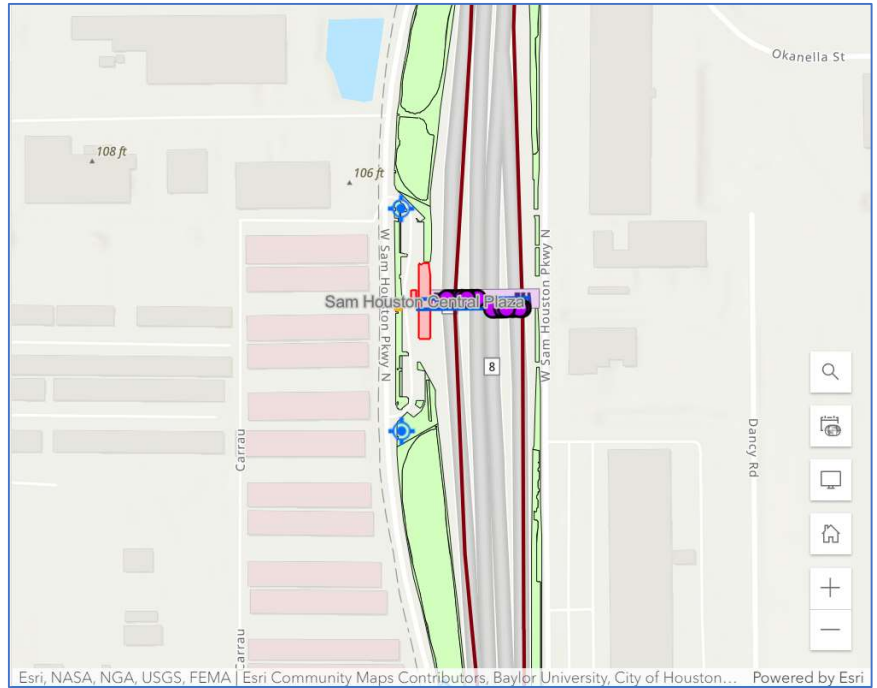


Figure 1. Focused screenshot of the Sam Houston Tollway and different assets that are maintained. This Picture includes Illumination, Mowing, Roadway, and Facility Buildings.

New feature layers have been created to record assignments as well. The Dispatch Assignments feature layer (Argento 23) represents the location and status of assignments. Users are now able to create and edit this feature in Field Maps(Esri 5) and the Experience Builder (Esri 1) application. Field workers also have the option to use Survey123 (Esri 4) on mobile devices in the field to update assignments they are responsible for via a link in the field maps.

To make it easier for dispatchers to assign incidents to specific teams, Maintenance Zones (HCTRA 25) and Contractor Sections (HCTRA 26) were also created and added to the Dispatch Assignments Map (Argento 9). Figure 2 shows how these features help separate areas of responsibility.

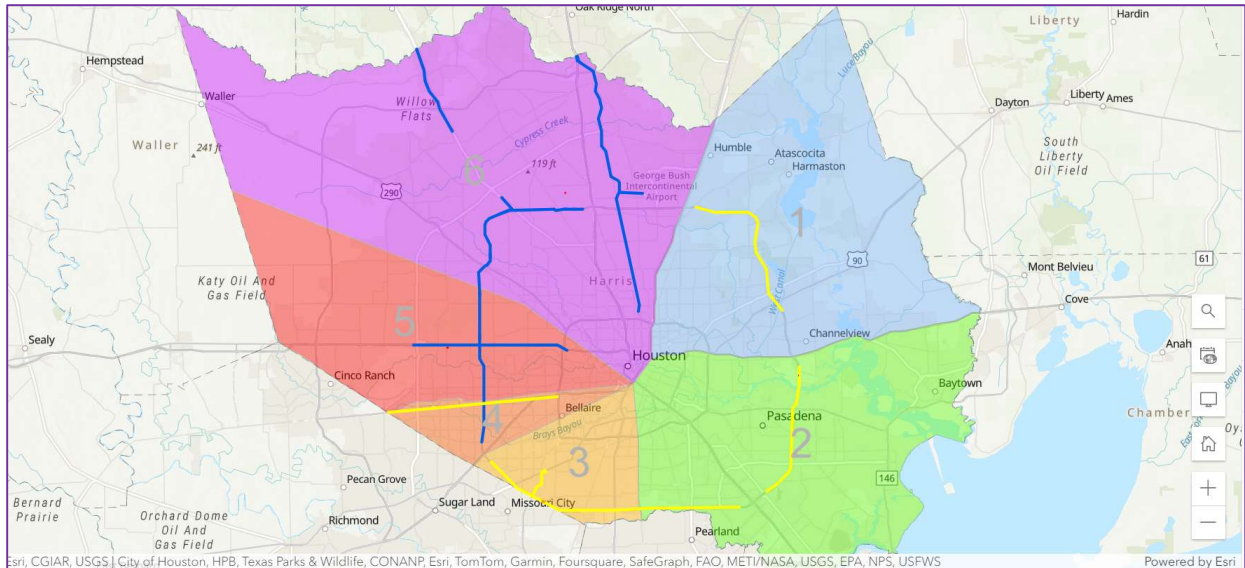


Figure 2. New feature layers were created to help separate areas of interest. The colored polygons separate different roadway inspection teams, and the blue and yellow polylines represent the actual roadway responsibility.

Knowing the zone locations is key as it will help determine which email groups receive alerts. Further development of the application will include email alerts using Microsoft Power Automate (Microsoft 27). This email will incorporate attributes captured with Survey123(Esri 4) from the Dispatch Assignments layer (Argento 23). Two fields within the Dispatch Assignments Layer (Argento 23) include journal entry fields that will be connected to related tables. The HCTRA Journal Entry (Argento 28) and Contractor Journal Entry (Argento 29) will help give more context to the assignments and can give the team a way to look back at the history of an event if needed. Previously, notes were overwritten in Microsoft Access and old notes were lost. These tables will also be incorporated into the Survey123(Esri 4) form for easy updates and reference to previous events.

Although there are 29 data sets listed for this project, only the Dispatch assignments and its two related tables will be editable by users. All other data sources are locked for editing to prevent any accidental deletion or movement. ArcGIS users are placed into a Maintenance Dispatch Group in ArcGIS Online (Esri 3) to gain access to the Maintenance Dispatch Application. This ensures only authorized users who have been properly trained can be given permission by a GIS administrator to add data to the project.

Presentation of Results

By using my data sources and methods, I was able to create an application that combined several different tools and software into one application. Every component was housed in Experience builder to create a user-friendly interface. This means that the dashboard, web maps (desktop and mobile), and survey123 were organized into only two main pages instead of 4 different applications.

The first page displays the dashboard which is an embedded window that uses the URL of the dashboard application. This was placed as the first page so that when users opened the application, they would immediately get a picture of the entire toll road system's status. The design of this dashboard was created with feedback from the toll road managers during meetings to address their needs. Figure 3 shows the dashboard set up which can display several key points of information that helps users narrow down search results and sort through assignments to pinpoint problem areas. The data in the dashboard was populated by inputting older assignments from the previous database manually as well as newer points created by office and field staff.

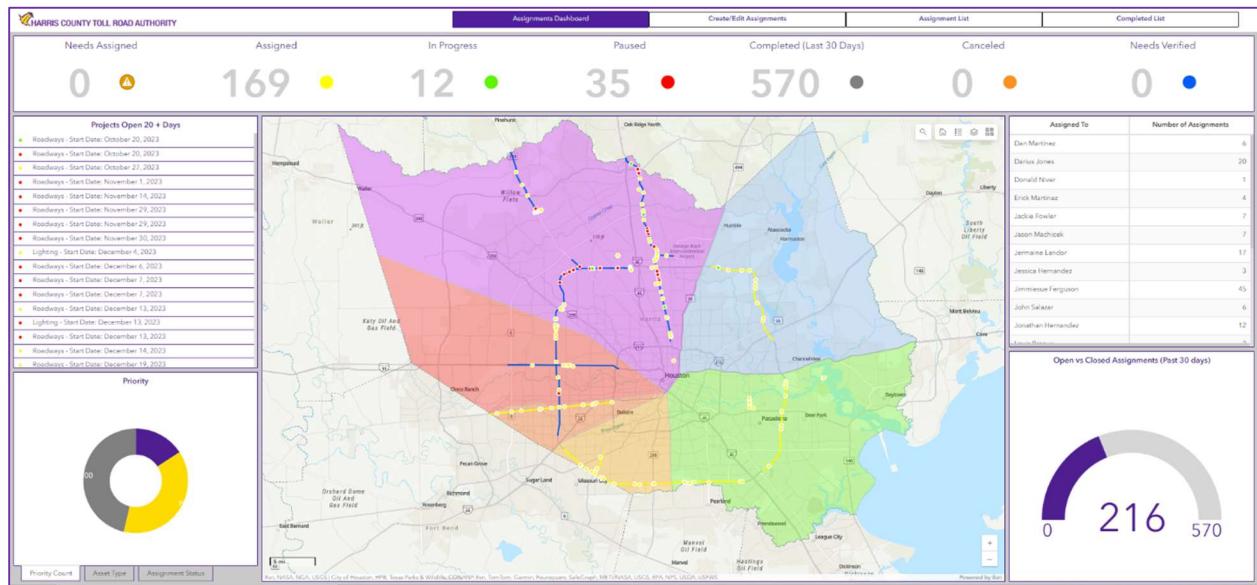


Figure 3. The Dispatch Assignments Dashboard provided the user with a large overview of the toll road system when allowing them to quickly narrow down information when needed. The lists are interactive and filter data based on selections. The charts at the bottom will change as the extent of the map changes.

The second page on the experience builder was designed with the Dispatch team in mind. I was able to shadow the team as they recorded assignments and then notified specific personnel. This helped me plan the layout of this page. The main goal was to provide a faster and more accurate solution for the team, while preserving as much of their original workflow as possible. Figure 4 shows the second page of the application. The dispatch map was added to the left side of the page. It includes a filter to quickly narrow down current assignments as well as the ability to search several fields from the assignments layer. An editing widget was added for the dispatch team to quickly drop points on the map when a problem is reported. The column on the right side of the page contains the survey123 form. When a user clicks on a point in the map, the survey column will sync with the point to show the form related to that specific assignment. This link helps users capture new data for the point as well as update data as the assignment progresses. The survey was designed to help the dispatcher capture a large amount of information in a short amount of time. There are multiple choice questions, specific questions that appear if other questions are answered a certain way and built in calculations that help auto populate answers so that the assignments can be submitted faster and limit the amount of mistakes. There is a

repeat function that is built into the notes section that allows users to input multiple notes so that a history of the assignment can be properly recorded.

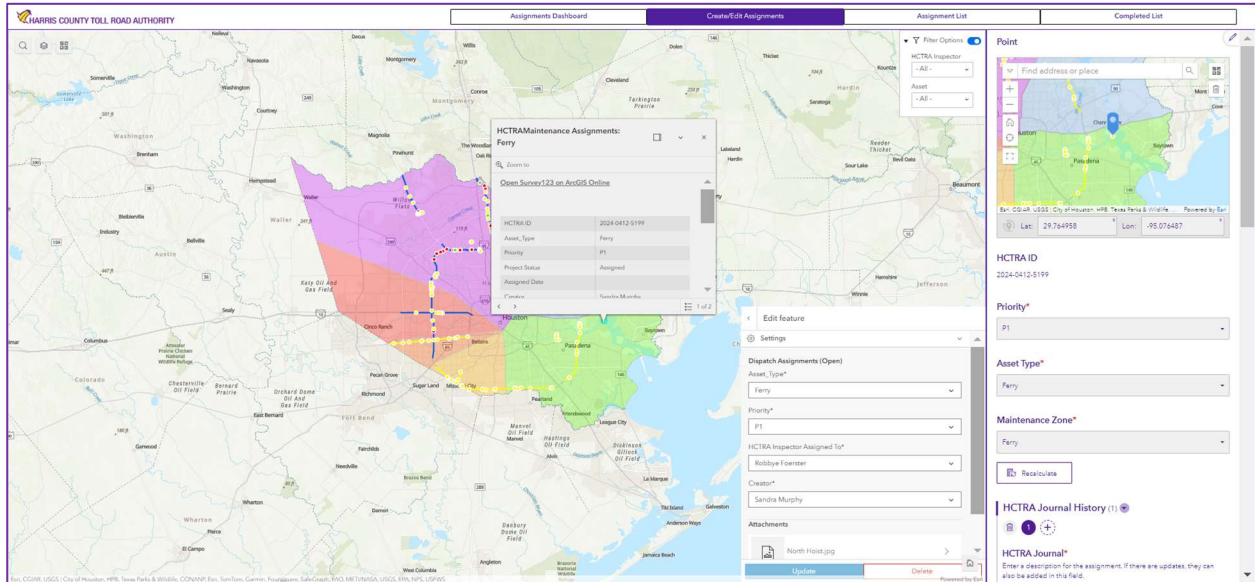


Figure 4. The Create/Edit Assignments page combines a web map with a survey123 form. This gives data collectors a faster and accurate way to create assignments. Utilizing survey123 to populate the attributes gives the user a better experience than an ordinary attribute domain.

Two more pages were added to the application that provides the users with attribute tables for active assignments and assignments closed within the past 30 days so that data about the assignments could be exported in table form instead of a map. The tables were not made editable so the focus on creating or editing assignments must still be completed on the second page. Other workflows regarding the dispatch assignments still rely on table information but were outside the scope of this project. These tables still provide these workflows with a data format needed so that no disruption occurs.

The field map application was designed for users to submit assignments themselves if the dispatch team isn't available or something needed to be reported quickly. Just like the Create/Edit Assignments page of the Experience Builder, users will drop a point on the web map and create a new assignment. Users can then click on a link to Survey123 within the pop-up window of the point, where they can fill out the information for the assignment and submit the report. The main difference with the mobile version is that the user only sees the map or the survey at one time. This is acceptable due to the smaller screen real estate of a mobile device and the experience of only opening one application is the same as with Experience Builder. Figure 5 gives an example of how this is displayed on a smartphone.

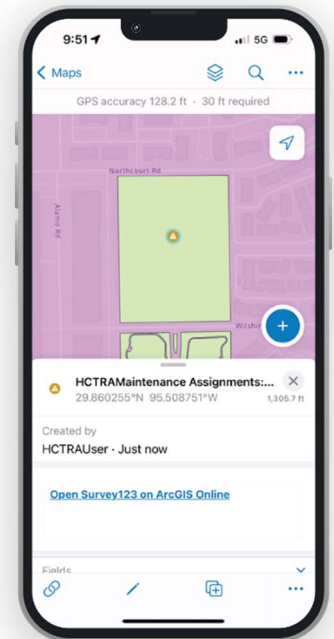


Figure 5. This field map application is used by toll road inspectors to create assignments in the field, rather than relying on calling the problem into the dispatch team. Users of this application can drop new assignment points and then use the survey123 link to fill out the details of the assignment.

Discussion and Important Takeaways

The dispatch team and toll road inspectors are still testing out the application, but feedback has been positive. The teams are still using the old workflows as a backup until the application is completely ready to go live and we are still holding weekly training and feedback sessions. The application still needs an automated email notification, which I'm creating in Power Automate. Once these email alerts are finished the application can go live and the teams can completely rely on the new workflow. The feedback has been positive, and the toll road inspectors find field maps and survey123 very helpful when they need to create an assignment in the field. The dispatch team has reported that they are able to report the same information as before but with faster response times. They enjoy the drop-down menus and automated answers. The survey form has helped cut down on manual writing and there are no longer variations of the same answer. This has also made it easier to filter for specific fields and get accurate results.

When I started to design this application, I set out to create a workflow that integrated GIS, eliminate manual data entries, record data from the field, and store information in an SDE database. Using ArcGIS applications for desktops and mobile devices has helped bring our toll road team into the modern era. Instead of recording data in a spreadsheet the team can now record data that can be visualized the instant it is created. This technology has also helped speed up the data entry process. By developing a survey123 form, I was able to provide the users with more efficient ways to create assignments and update their attributes. Instead of writing notes, making spreadsheet entries and then phone calls, the team can now enter the data once and it can be shared with everyone.

Field inspectors used to rely on the dispatch team to create every assignment and had to phone in reports of incidents. Now they are empowered to make these assignments themselves. This is especially

beneficial when working the night shift or on call on weekends when the dispatch team isn't available. Reporting the incidents firsthand has also helped the assignments become more detailed and accurate. Since the experts in the field are the ones making the reports, the data comes from first hand rather than notes jotted down during a phone call. All the data created is now stored in an SDE SQL database rather than a disconnected Microsoft Access database. This creates the ability to share this data with other applications and software. There are already plans to incorporate this database into asset management software once the GIS data and the application have been established.

type	name	label	hint	guidance_hint	appearance	required	required_message	readonly	default	calculation
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text	HCTRAID	HCTRA ID						yes		
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select_one HM_Assignments_AssetType	Asset_Type	Asset Type			minimal	yes				
select_one HM_Assignments_MaintenanceSection	Maintenance_Zone	Maintenance Zone			minimal	yes				iff(selected({\$Asset_Type}, 'Facilities'), 'Facilities', '')
select_one Facility_Type	Facility_Type	Facility Name			minimal					
note	History	Address								\${adCal}
select_one Facility_Assignments	Facility_Assignment	Facility Assignments			minimal					
text	Other_Assignments	Other Assignments								
select_one Roadway	Roadway	Roadway			minimal					
select_multiple Location_Description	Location_Description	Location Description								
select_multiple Cross_Street	Cross_Street	Cross Street			minimal					
select_multiple Direction	Direction	Direction			minimal					
select_multiple Lane_Location	Lane_Location	Lane Location			horizontal-compact					
begin repeat	HCTRAMaintenanceJournal	HCTRA Journal History								
text	HCTRA_Journal	HCTRA Journal	Enter a description for the assignment. If there are upda	multiline		yes				concat(format-date(now(), '%m/%d/%Y'), ':')
end repeat										
note	HCTRA_Journal_History	Every Journal Entry			hidden					join(" -->", \${HCTRA_Journal})
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Figure 6. This XML for helps GIS users develop a custom survey form with interactive questions and gives the users a unique experience depending on their previous answers.

Achieving these goals was a difficult process. Building the applications and combining them into one central tool was a new change for me. I have made web maps, surveys, and dashboards for previous work, but I had never created a project this complex that combined different software into one application. Creating a complex Survey123 form took the most time to develop. Most of the Esri software uses a GUI interface to design the application. Survey123 however, uses an XML form to design and format the questions in the form. I found this the most difficult to learn. Figure 6 shows a screenshot of this XML form. You can see that the user can create the forms without major coding but have the option to add calculations such as if statements or text manipulations.

One unique challenge that I didn't realize would come with this project was finding an efficient way to capture the needs of the users. I had to have more meetings than I anticipated and changed the attributes of the assignments multiple times after having the team give input on the project. It was challenging to anticipate situations or problems that could occur on the road. This meant that I had to keep adding question types to the survey. I learned a lot about project management and how to ask the right questions from the start of a project to limit the number of revisions that would need to be made later.

I believe that an important take away from this project was that I was able to show the dispatch and maintenance teams how GIS could improve their quality of work. The team has been very responsive and given a lot of good feedback about using this application. There have already been some new suggestions to create new apps for other tasks such as inspections and asset audits which suggests they have bought into the idea of integrating new technology into their everyday work life.

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