LA COUNTY-ANALYTICS PILOT

Building a Geo-Cyberinfrastructure for Emergency Management of Trail Systems in Los Angeles County

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1. Introduction

The 2003 National Survey on Recreation and the Environment reported that 97.6% of Americans over the age of 16 participate in some type of outdoor recreation activity each year (Heggie & Heggie, 2008). Moreover, activities such as hiking and backpacking are among the most popular and fastest growing outdoor recreational activities (Johnson, Huettl, Kocsis, Chan, & Kordick, 2007). The Department of Parks and Recreation in Los Angeles County (LA County) offers a wide range of recreational opportunities from horseback riding to mountain biking trails and moonlight hikes on over 60 trails. However, the risk of injury and illness comes with those opportunities and requires search, rescue and/or emergency medical service interventions. An retrospective study of injuries within Yellowstone National Park, for example, revealed that 59.2% of the reported injuries required emergency medical system transport (Johnson et al., 2007). For the cases that required emergency medical services, it is sometimes very difficult for the rescue team to find the spots where someone was injured.

For the LA County trail systems, there are challenges identifying the best route to the emergency locations because the numbering systems of different trails are independent, and there is no unique signage. The trails in LA County currently rely on mile markers to indicate the distances from access points; thus, to gather full information about the reported location, the rescue team needs the full name of the trail, the mileage referred to on the nearest mile marker and the location of the access point used to calculate the mileage. There is also the problem that the trail names often overlap. For example, there are trails named Schabarum-Skyline Trail – San Gabriel Valley Overlook, Schabarum-Skyline Trail – Extension Connector, Schabarum-Skyline Trail – Colima Parking Connector, Schabarum-Skyline Trail – Azusa/Colima Connector, and Schabarum-Skyline Nike Missile Site Connector. These names are extremely long and share many common words. The third problem is that the trail access points do not always delineate the best route for reaching the victim. In many cases, the reported location is more accessible using a nearby road segment or another trail that intersects the one on which the victim is located. A fourth problem is that some of the intersections between the trail systems and the road networks are not well defined. For example, the navigation systems that rely on the road networks will not help the emergency response teams in the cases where the road crosses over or under the trail itself. Overall, these problems taken as whole result in a high risk of transcription errors on reporting the location between the caller and responder and thus lower the efficiency in locating and rescuing the reported injury victim.

To overcome the challenges mentioned above, LA County collaborated with Accenture and the USC Spatial Sciences Institute. We worked together to develop an addressing system on LA County's trails and to route emergency medical services responders to the correct location via one or more multi-model transport options (i.e. routing along the road network to the optimal access point, and continuing along the trail network). This pilot study expanded the LA County Countywide Address Management System (CAMS) to include the trail systems in LA County within a cyberinfrastructure with solutions for the four challenges noted earlier. The solution satisfied the following pair of requirements: (1) it would work on all of LA County's trails and not just the trail chosen for this use case; and (2) it was compatible with the current CAMS used by LA County. The solution is illustrated using the Emerald Necklace, a long series of bicycle, equestrian and walking trails that extends 17 miles and connects the San Gabriel River, the Rio Hondo, and several parts and a local Nature Center in the Whittier Narrows. Figure 1 shows the locations and extent of the trail systems that comprised the use case in this study.

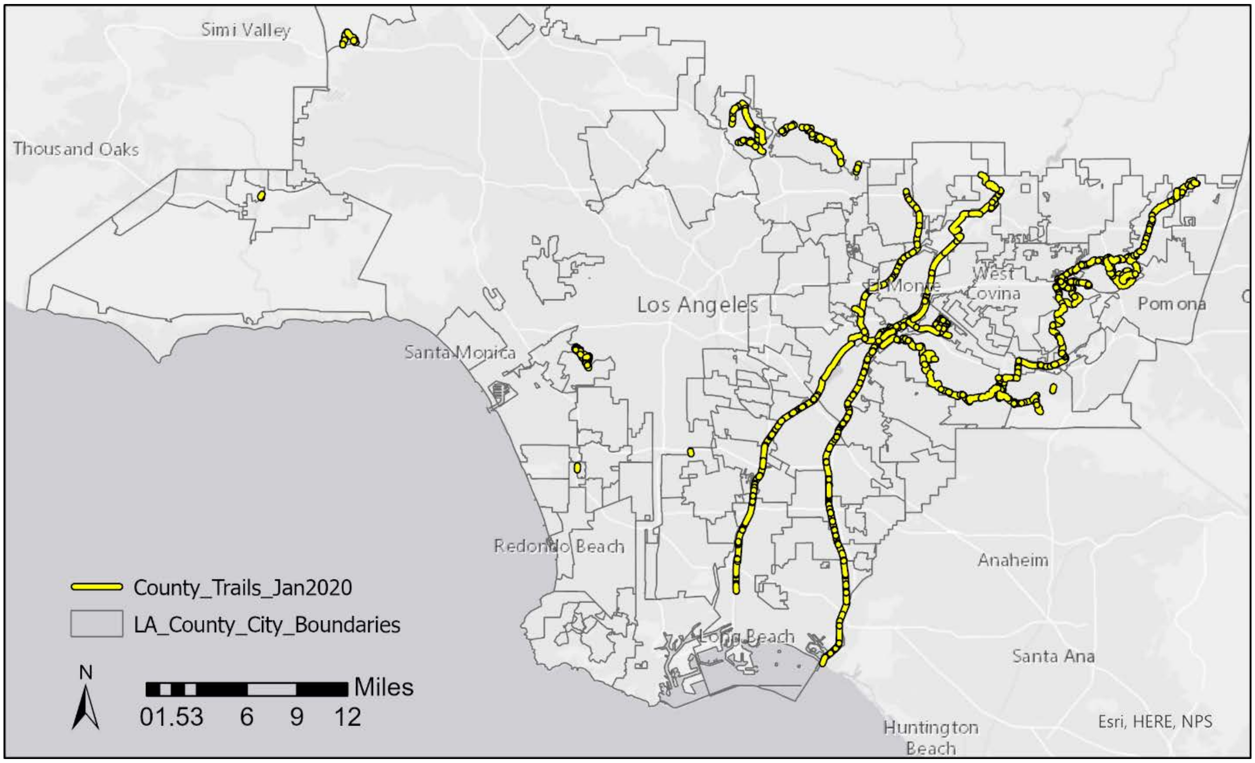

Figure 1: The Emerald Necklace

2. Locating accidents and routing rescue teams to accidents on trails

On October 15, 2017, a 47-year-old man suffered a heart attack on a trail in Cold Spring Harbor State Park on Long Island, NY. The man collapsed at marker 108, one of 15 small signs placed less than one-tenth of a mile apart from each other along the rugged trail surrounded by oak, red maple, American beech, and other tree species. The heart attack victim's wife called Suffolk County's Enhanced 911 system on her cell phone and reported the trail marker number, posted on a tree that her husband sat slumped under. The first responders then consult a digital map of the trail markers to obtain the reporter's geographic coordinates and additional information that will aid in the rescue. "The information the map provides to first responders shaved about 10 to 15 minutes off the response time to a medical emergency that occurred on the trail", said Garside, a Suffolk County police officer who patrols the area. The story noted the importance of a digital numbering system in helping emergency teams to find and rescue the victims (Esri, 2019).

In order to quickly respond to reported issues on trails and reduce the risks of transcription errors, the framework of this pilot study was more complicated than simply mapping the locations of the mile markers. It involved designing a numbering system that would work for all the trails in LA County as a whole system, modifying the information printed on the existing mile markers and streamlining the geocomputation processes to output the optimal routes and travelling methods to the reported locations on trails. The geocomputation process works in real time and uses the traffic information from the Google Maps service at the time of the reported case to identify the best travel option(s). The final output involves one of three options. The first entails finding the nearest road segments from CMAS and directing the rescue team to use vehicles to gain direct assess. The second entails finding and traveling to the best access point and suggesting that the rescue team continue on foot to the reported location. The third entails suggesting that the rescue team use a helicopter due to the lack of options to use the local roads and/or trails. Figure 2 shows the geocomputation workflow to support the rescue and treatment of the victim(s).

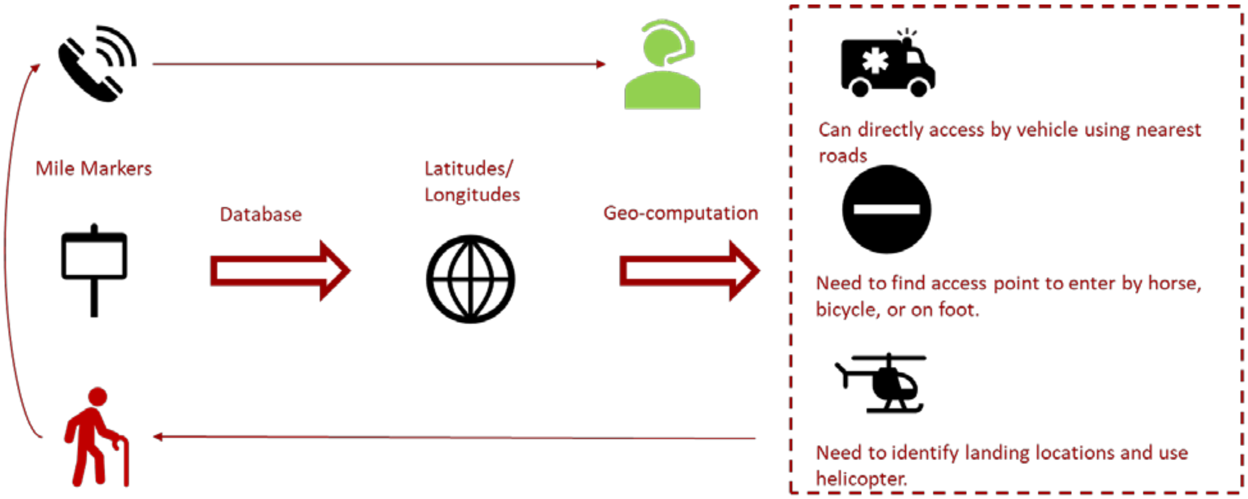

Figure 2: Design of geocomputation workflow

3. Cyberinfrastructure Design

“A Cyberinfrastructure is a combination of data resources, network protocols, computing platforms, and computational services that brings people, information, and computational tools together to perform science or other data-rich applications in this information-driven world” (Yang, Raskin, Goodchild, & Gahegan, 2010). We constructed a fully functional cyberinfrastructure that supported three tasks. The first enables the users (the emergency service providers; e.g., the 911 dispatchers) to use and explore the routing systems over the web without encountering the costs and complexities of the underlying hardware, software, and required development capabilities. The second combined multiple map, data, and analytics services for the users and output an integrated, intelligent, and interactive map service to output the optimized rescue strategy. The third provided a common environment in which the future development and maintenance team (e.g. the LA County Department of Recreation and Parks) can evaluate a wide range of datasets, maps, scripts, web-based geoprocessing services, hand-on decision support tools, and GIS analysis models in future iterations of the cyberinfrastructure. We implemented the cyberinfrastructure design outlined below to accomplish the three aforementioned tasks

The cyberinfrastructure provides users (e.g. 911 dispatchers) with the tools and data to quickly identify the reported location on the trail addressing system and calculate the best routes and access methods to take the emergency teams to these locations. The cyberinfrastructure relies on the information printed on the mile marker nearest to the reported incident from the caller and outputs the most appropriate access routes and travel methods. The vortex of the cyberinfrastructure is the python-based web framework driven by a micro framework called Flask on the Jinja template engine and the WSGI toolkit. We chose Flask rather than other popular PHP web frameworks for the ease of integrating the geocomputation functions we worked with in Python. We also integrated Google Maps API services into this cyberinfrastructure to view the streets and the reported location, if possible, and to find the nearest road segments and calculate the walking time to the reported location from the nearest road segment(s). The database layer of the cyberinfrastructure contains spatial data cast as structured data frames, unstructured KMZ and GeoJson files, and serialized Pickle files. Most of the spatial datasets were prepared using ArcGIS (i.e. ArcGIS Pro 2.0, and ArcMap 10.8). The cyberinfrastructure also generates an output layer to convert and store on-the-fly results in ArcGIS. Figure 3 shows the cyberinfrastructure design. The outputs include using embedded services through web browsers or other smart devices (the double headed arrow in Figure 3 show on-the-fly reactions), or information that is directly importable into the ArcGIS geodatabase (the dashed line in Figure 3 that points to additional opportunities for further analysis and visualization).

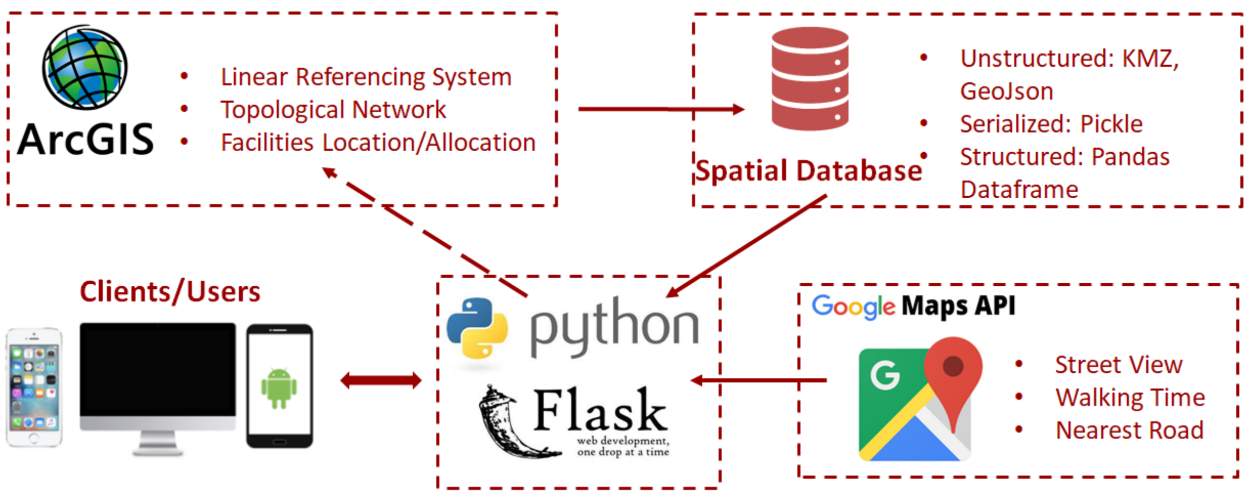

Figure 3: Cyberinfrastructure design

4. Preferred signage for a linear referencing numbering system

The development of a numbering system ties public locations to a location reference system. This allows a person who needs some sort of emergency assistance to convey the corresponding location to the emergency service team. Typically, these numbered markers take the form of signs on the trails that are clearly visible to users (e.g. hikers). There are currently four major numbering systems used on trail systems: (1) the U.S. National Grid (USNG); (2) a locally curated and imposed numbering system; (3) a sequential numbering system; and (4) an access numbering system (City MTB, 2019). The latter three options are linear referencing systems and require fewer signs to be printed. Choosing the best option for a given trail system generally requires communication with the emergency services personnel in the area.

Our team worked with the LA County Department of Recreation and Parks on a few proposed numbering systems and finally developed an alphanumeric access numbering system to facilitate navigation on the trail systems during an emergency to minimize the risk of transcription errors between the trail user(s) and the 911 dispatcher. The recommended alphanumeric linear referencing system, which was vetted by LA County and Accenture, offered numerous benefits over one using a combination of full trail names and mile markers. For example, it not only improved the ability for hikers to communicate their locations but also made the process of locating and routing to those locations more efficient for responders, because it used the cyberinfrastructure and relied on the unique signage proposed for every trail in the LA County trail system.

This new addressing methodology is composed of two parts:

- An alphabetical (3 letter) part: this was generally created by using the first character of the first three words excluding dashes, e.g. Van Tassel Trail = VTT, La Canada Open Space Trail = LCO.

- A numeric (3 digit) part: this was created by using a prefix number (1 digit) determined by the number of trails within the system plus a sequential value determined by a sequential linear referencing system (2 digits), e.g. 100, 101, 102, 103, ..., and 200. 201, 202, 203 ….

This particular combination ensures that no two alphanumeric numbers will be the same across the whole trail system in LA County. The procedure to create this alphanumeric numbering system builds on the existing mile marker data from the LA County Department of Parks and Recreation, in order to streamline the process used for future implementation. The original Feature IDs (not unique) of the trail addressing system were preserved and served as a connection between the new sequential numbering system and the existing mile maker dataset. In this way, the procedure for creating the linear referencing numbering system and signage is easy to implement on other trails and trail systems in LA County.

The alphanumeric mile marker system along LA County trails will benefit everyone on the trails by: (1) improving the ability for hikers to communicate their locations because the codes are easy to understand; and (2) making the process of finding these locations more efficient for responders because the codes are sequential. We added the points to the cyberinfrastructure mapping system where users will be able to input a given alphanumeric address point and receive an output of the access point(s) nearest to that particular alphanumeric point, and this would allow responders to more efficiently and effectively locate and travel to the correct locations.

5. Network analysis and accessibility assessment

After an alphanumeric number is reported to the emergency responder via a phone call or text, the cyberinfrastructure will perform three tasks. The first is to identify and visualize the reported location. The second is to find the best access point through a pre-built topological network, and the third is to determine the best access method(s), such as by driving to the reported location or driving to a nearby drivable location and sending a rescue team on foot or by helicopter in difficult terrain to the reported location. In the cases where the corresponding location is not directly accessible by vehicle, the cyberinfrastructure will output a series of alphanumeric numbers for the rescue team to follow on the reported trail.

To assess the accessibility of reported locations, we leveraged the Google Maps API services and combined their outputs with the CAMS. CAMS has road segments that overlap with the trail systems, and it documents variables indicating the vehicle accessibility of the overlapping road segments. If the reported location lies on a road segment in CAMS, the cyberinfrastructure will initially follow the road accessibility stored in CAMS and in other instances, it will check the Google Street View service, and use it to assess the accessibility. In the event no direct accessibility is found by either approach, the cyberinfrastructure finds the nearest road segment by using the Google Map Roads API service, and calculates the walking time from the road segment to the reported location and compares this result with a preset threshold to assess accessibility. For example, if the walking time is 20 minutes and the threshold is 10 minutes, the system will decide the corresponding location is inaccessible. If the location is inaccessible by any means, the cyberinfrastructure will search for other close locations (so called access points here) on the trail that may grant accessibility (e.g. other trail access points or intersections between trail systems and CAMS roadways).

To find the best access point to connect to the reported location, a topological network for the trails was constructed. This topological network keeps all the topological relationships of the trail system, manages information about the signs and maintains the connectivity among the signs, so that the navigation distances between each sign and the reported location in the topological network could be calculated. The cyberinfrastructure will evaluate the travel cost of the potential access points close to the reported location to identify the best access point. The calculation of the best access point relied on the Location-Allocation service from ArcGIS Pro 2.0, which finds the best locations for facilities (access points) to serve a set of demand locations (reported locations).

In this pilot study, trailheads initially served as access points. If no access points were found with this protocol, the cyberinfrastructure will suggest using a helicopter for emergency services. Figure 4 shows two cases on the Emerald Necklace trail system. The first case is a quarter of a mile from the nearest road access to the Schabarum Grand Spur Trail. This access was accessible by vehicle via 2400-2540 N Grand Ave, Covina, CA 91724. The second is 2.5 miles from the nearest road access on the Rowland Heights Loop Trail. This access was not accessible by vehicle, since the closest address that a vehicle could reach is 18753-18799 Pathfinder Rd, Rowland Heights, CA 91748. For the second case, the rescue team would need to compare the traveling costs by horse, by bicycle, or on foot from the given access point to the reported location using cyberinfrastructure and seriousness of the accident to decide whether to use helicopter or not.

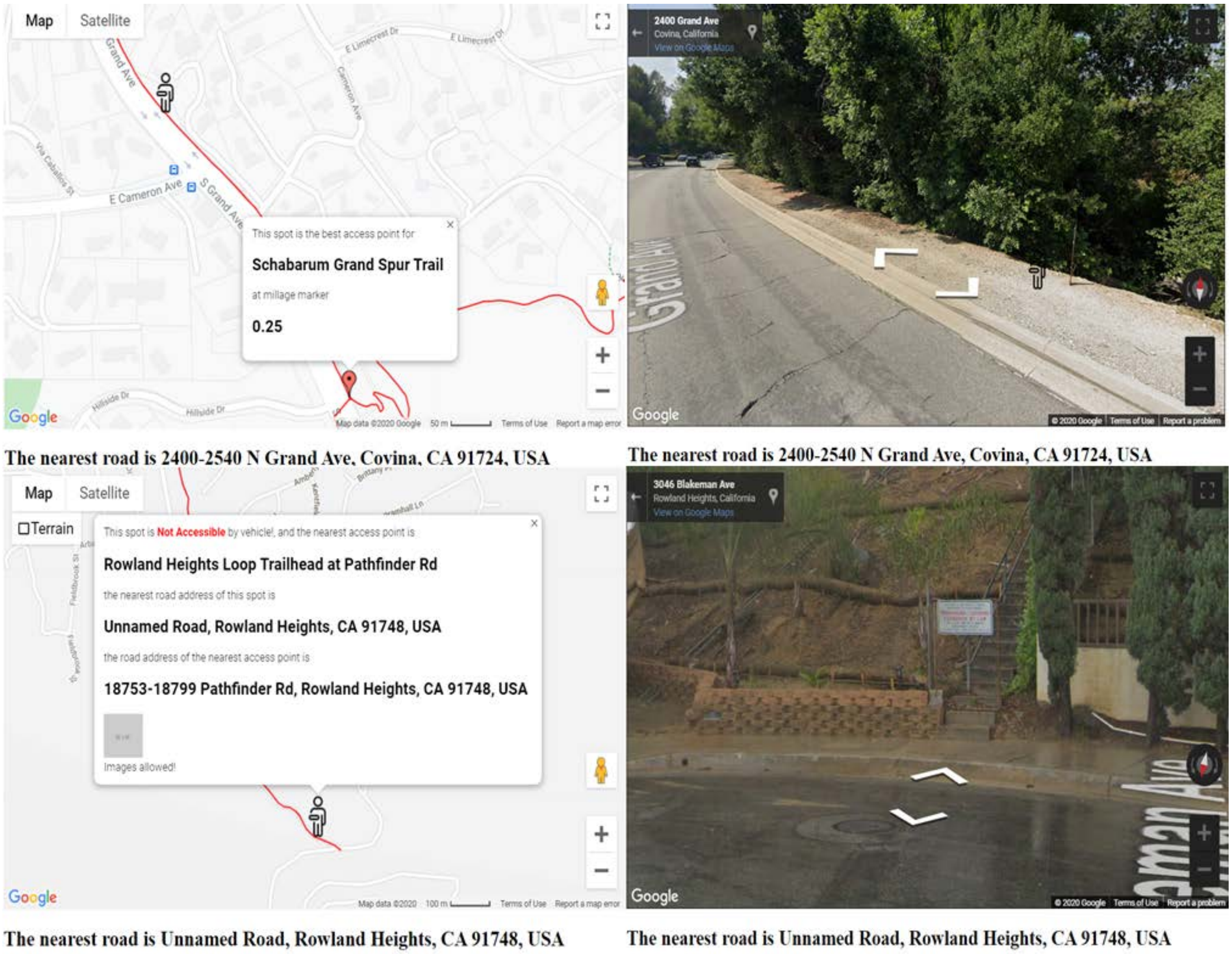

Figure 4: Examples showing accessible and inaccessible locations on the Emerald Necklace trail system

6. Summary and next steps

This pilot study developed a cyberinfrastructure with a new linear referencing numbering system for the trails in LA County using the Emerald Necklace trail system as a case study. The cyberinfrastructure allows emergency service responders to more efficiently and effectively locate and navigate to the reported locations where an accident occurred. There would also be less risk of transcription errors between the reporter and the emergency service responder due to the new alphanumeric codes assigned to the signs that follow the preferred Access Numbering System. The current version of the cyberinfrastructure works with the current trail addressing system for easy implementation and can be expanded and used in additional trails and trail systems.

For next steps, one could examine other possible access points in the topological network besides trailheads (e.g. intersected points between CAMS and the trail networks). Further examination of the accessibility of those points relies on a more detailed 3-dimensional topological network. For example, in the case of an intersection point on an interstate highway running above a trail, the closest exits on the highway will be required to help define the access route. In addition, some new access points that do not constitute intersections connecting the CAMS with the trail networks or access points could be extracted from high resolution satellite imagery and added to the topological network. Finally, the cyberinfrastructure could be modified to utilize real-time traffic information from Google Map services to adjust the travel time costs (e.g. travel times or distances) to reach the reported locations.

The final deliverables from this pilot project included: (1) the source codes of the cyber-infrastructure with instructions on how to set up and deploy the required environment; (2) a help document with a demo showing how to use the cyberinfrastructure; and (3) preliminary results including the geocomputation results and the processed spatial datasets.

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