R&A Engineering

Non-Recurring Congestion Mitigation Solutions for the Washington District Department of Transportation

Using Third-Party Navigation Applications to Improve Transportation Operations Planning for Special Events

R&A Engineering

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10. Abstract	This document presents a high-level concept-of-operations for using third-party data applications to improve non-recurring congestion within the city limits of Washington D.C. The information contained herein reflects information provided by a representative of the District Department of Transportation (DDOT) to clearly identify the current state of the transportation network and identify critical areas for improvement. DDOT's highest priority needs related to non-recurring congestion management are described and a two-part solution for addressing these needs are introduced.
11. Original "Problem" Statement from DDOT	"There are now a number of widely used applications for vehicle navigation on the market. These applications have tremendous potential to improve both DDOT's internal situational awareness and DDOT's ability to provide information to the public during major special events. With this in mind, the project team will develop concept of operations for DDOT to 1) use historical, third-party application data from similar events to inform adjustments of road closures, parking restrictions, and traffic control for future events; and 2) systematically push important information on road closures and other roadway restrictions to the public via third-party applications before and during special events."
12. Number of Pages	Concept-of-Operations: 10 Pages | Additional Resources: 12 Pages

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List of Acronyms

DDOT	District Department of Transportation
DPW PEMA	Department of Public Works Parking Enforcement Management Administration
MPD	Metropolitan Police Department
TOPP	Traffic Operations and Parking Plan
TOPS	Transportation Operations Permitting System
TNC	Transportation Network Companies (e.g., Uber, Lyft)
VMS	Variable Message Sign
WMATA	Washington Metro Area Transit Authority

1 Overview

This document presents a high-level concept-of-operations for using third-party data applications to improve non-recurring congestion within the city limits of Washington D.C. The information contained herein was provided by Ms. Kelli Raboy, a representative of the District Department of Transportation (DDOT), to clearly identify the current state of the transportation network and identify critical areas for improvement. In this report, DDOT priorities related to non-recurring congestion management is described and a two-part solution for addressing the identified needs is introduced.

1.1 Motivation

According to the 2017 INRIX Scorecard Index, Washington D.C. is the sixth most congested city in the United States with an annual average lost time of 63 hours per driver. In a region the size of Washington D.C., this results in a total productivity loss of over six billion dollars (*1*). Congestion can be divided into two categories: recurring and non-recurring. Recurring congestion is regular and expected, induced by typical traffic volumes on a normal travel day. Non-recurring congestion represents atypical network inefficiencies resulting from additional stress placed on the network (e.g., special event, lane closure, crash, adverse weather conditions). On average, 50% of congestion is recurring, while the other 50% is non-recurring (*2*, *3*). Management and mitigation of all congestion is a priority so to improve network reliability and maintain traveler confidence.

A specific challenge associated with the traffic congestion in the District is the large proportion of commuter traffic. Although the District houses approximately 660,000 residents within its city limits, the city more than doubles in size each day with visitors (approximately 125,000) and commuters (approximately 600,000) (*4*). Moreover, despite the availability of commuter rail, metro, and bus service, almost two-thirds of daily trips are made by automobile (*4*).

1.2 Operational Objectives

DDOT has been aggressive with their approach towards reducing recurring congestion by investing in Intelligent Transportation System (ITS) strategies to facilitate contraflow operations on key corridors, inform travelers of anticipated travel times, and enable optimal travel decisions. However, <u>DDOT is interested in innovative solutions to address non-recurring congestion</u>. Non-recurring congestion is caused by a variety of different conditions and events. These sources of non-recurring congestion can be generalized into three categories: (i) road closures, both scheduled (e.g., construction or utility work) and unscheduled (e.g., traffic collision); (ii) increased demand, due to an add influx of vehicles for a specific event; and (iii) inclement conditions, such as adverse weather or roadway conditions. In recognizing the sphere of influence of the agency, DDOT identified two key objectives that would have the greatest potential for network-wide improvements: (i) <u>improved traveler information related to scheduled road closures</u> and (ii) <u>improved operational strategies during scheduled special events</u>.

1.3 Approach

In order to address the two aforementioned objectives, a complementary two-part solution was developed. The general approach to each part of the solution is summarized below:

(1) The first part of the solution addresses the current road closure permitting system used by DDOT to schedule road and utility work throughout the District. Updates to the current permitting system are recommended and an improved real-time application for tracking current road closures is introduced. In addition, a procedure for interfacing the solution with a database server is recommended to facilitate seamless transfer of road closure status to third-party applications used by local travelers to influence traveler decisions.

(2) The second part of the solution addresses the use of historical data to improve traffic operational strategies to mitigate congestion before, during, and after planned special events (e.g., sporting events). A thorough review of internal and external third-party application data sources available to DDOT is completed and a unique solution using these data is introduced. The recommended strategy is intended to be continuous: proposing operational strategies, identifying the impact of the implemented strategies, and then updating the traffic control policy plans based on those experiences.

1.4 Stakeholders

A comprehensive list of stakeholders was identified to ensure the proposed system matches the needs of all users and agencies. A block diagram illustrating the interaction of among stakeholders is shown in Figure 1.

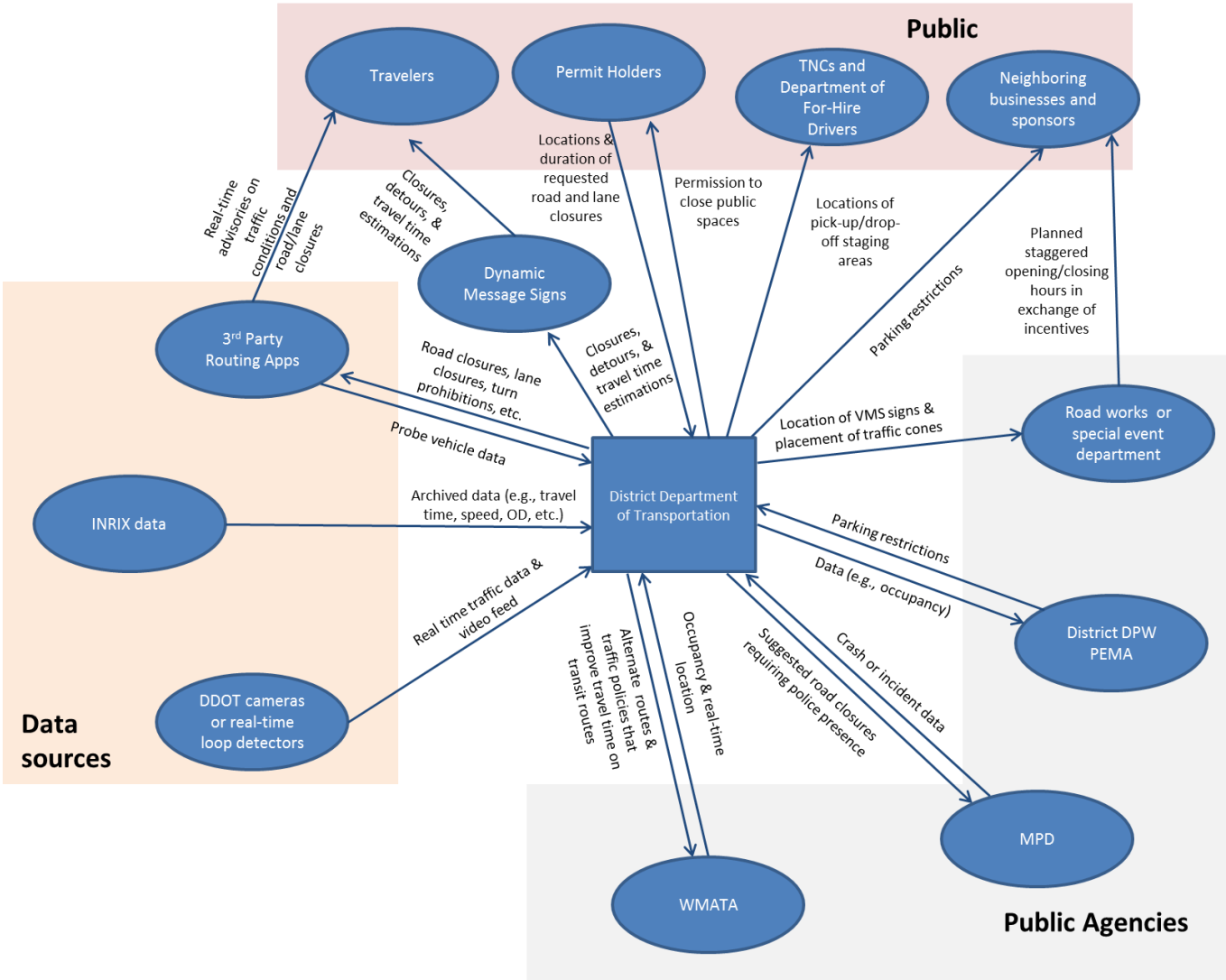

Figure 1: Block diagram of interacting stakeholders

1.5 Report Outline

The body of the report is divided into two sections that detail each part of the proposed solution addressing the DDOT management of non-recurring congestion. Within each, the current state of the system is described, the scope of the project is clearly stated, stakeholders are identified, and user needs are expressed. Next, the proposed solution that satisfies the user needs is presented. Examples of operational functionality are provided and the requirements for installing and maintaining the system are outlined. Finally, perceived benefits of the solution are highlighted alongside potential institutional barriers to the proposed solutions.

2 Part 1: Road Closure Permitting System

The first part of the proposed solution addresses the first objective of DDOT: improve traveler information related to scheduled road closures. The following sections paint a clear picture of the current state of the permitting system used by DDOT—Transportation Operations Permitting System (TOPS)—as well as the communication shortcoming with the traveling public. A current partnership with Waze, a widely used third-party navigation application, is discussed and leveraged as a method for efficiently communicating closure information to road users. Updates to TOPS and the development of an application to collect real-time closure information are recommended.

2.1 Problem Definition

To disseminate traveler information related to scheduled road closures, DDOT must:

1. Ensure that all necessary information is being collected from permit-holders closing roads.
2. Establish a new mechanism for requesting up-to-date or real-time information about active closures.
3. Develop a system that relays information related to active closures to the traveling public.

The current DDOT permitting system, TOPS, is common among state and local DOTs; it requires basic information from contractors related to the nature of their work and the timeframe in which they plan to perform the work (additional information available in Appendix A). The shortcoming from this standalone method is that specific timeframes for active closures are not requested and no additional procedure is in place to trigger the activation of a permitted closure in real-time. Finally, due to the lack of reliable real-time closure data, information is not readily available to the traveling public. The DDOT website is updated with a list of planned closures—with the general information available from the original permit request—however, the interface is not intended to influence real-time travel route or mode choices that could mitigate the non-recurring congestion caused by the closure.

2.2 Problem Scope

The scope of the presented solution is constrained to the three steps defined in Section 2.1. Minimal updates to the current permitting system are recommended; however, as this process is not central to the overall objective, the recommended changes are focused on ensuring compatibility with the newly proposed application. Next, three solutions for gathering detailed information about active closures are described. The solution with the greatest benefit-to-cost ratio is recommended and details related to its implementation are provided. Finally, a solution for communicating information with the traveling public is recommended. While multiple alternative scenarios exist for relaying information to the traveling public (e.g., 511 Systems, DOT websites, DOT-specific mobile applications), DDOT recognized the wide adoption of third-party navigation applications by its road users and entered a mutually beneficial agreement with Waze, the Connected Citizens Partnership. Through this partnership, Waze provides DDOT real-time congestion data from probe vehicles, and in turn DDOT agrees to provide information about scheduled road closures. Until this point, DDOT hasn't collected data at an adequate resolution to be shared with Waze (i.e., real-time and reliable information about active closures are required). Therefore, the scope of this solution includes a back-end system that automatically updates Waze on active closures by interfacing with the prescribed application for gathering real-time closure information.

2.3 User Needs

Considering the stakeholders in Figure 1, specific user needs were established.

UN 1.1: Real-time Identification of Active Road Closures

DDOT needs up-to-date information about current active road closures throughout their network so to inform travelers, partner-agencies, and internal managers.

UN 1.2: Reduce the Impact of Active Road Closures

DDOT needs to reduce the negative impact of active road closures by providing real-time alerts to road users and enabling them to make alternative route and mode decisions.

UN 1.3: Uphold Partnership with Waze

DDOT needs to provide Waze real-time high resolution data related to active closures.

UN 1.4: Remain Accountable to Travelers through Active Communication

DDOT needs to invest in a strategy to better communicate active road closures with the travelers to improve accountability and network-wide reliability.

2.4 Proposed Solution

The proposed solution is presented in the three steps introduced in Section 2.1.

2.4.1 Updates to TOPS

The TOPS system currently functions well as a log of planned closures; details related to the data fields currently collected by TOPS are available in Appendix A. To ensure compatibility with real-time protocols, the following additional data fields are recommended: presence of workers on roadway, details related to which lane(s) closed, expected traffic impact (e.g., minimal, moderate, severe), and nearby landmarks for qualitative description of impacted location.

2.4.2 Elicitation of real-time information about active road closures

Up-to-date or real-time information for active road closures can be collected in multiple ways. A survey of procedures used by other DOTs revealed multiple alternative solutions. For example, Missouri DOT uses an online platform, similar to TOPS, but requires that all permit holders meet with a DOT traffic area specialist before and after construction (*5*). Hawaii DOT uses their permitting system, traffic cameras, and field sensors to inform the public about active closures (*6*). Lastly, New York City DOT provides the public direct access to information about granted permits in the city (*7*). To meet all stakeholders' needs in the District, three alternative solutions are presented. Each alternative requires a different level of effort related to system installment and maintenance, personnel oversight, and data accuracy.

Alternative A | Daily Phone Calls: The Virginia Department of Transportation (VDOT) uses a permit-request system similar to TOPS. Detailed information about active permits is gathered by VDOT employees who call the primary contacts for permit holders on a daily basis to request their work schedules. Therefore, the first alternative is to designate a DDOT employee to make contact with active permit holders on a daily basis, gather updated information about daily work plans, format the information into an appropriate format to be shared with Waze, and disseminate the data.

Alternative B | Electronic Daily Update Form: The second alternative is similar in concept to the first; however, the information exchange is expedited through the generation of an electronic platform where permit holders update their daily work status (up to) 48 hours before the day of the scheduled work. All required updates must be recorded before 7AM on the day of the scheduled work, and the input information will be aggregated and disseminated to Waze each morning.

Alternative C | Electronic Check in & Check out Form: The third alternative is an electronic platform that could be used for real-time reporting of *starting* and *stopping* road closures. Using a web or mobile-based application, permit holders would "clock-in" when they begin work and "clock-out" when their work is complete. Immediately after a permit-holder clocks-in, pertinent information from their original permit application will be merged with their current status and disseminated to Waze.

In reviewing the relative benefits and costs of these alternatives, Alternative C was shown to have the greatest benefits when comparing the resulting data accuracy, required maintenance/DDOT personnel interaction, and system construction. This relative trade-off analysis is shown in Figure 2, and more details are available in Appendix B.

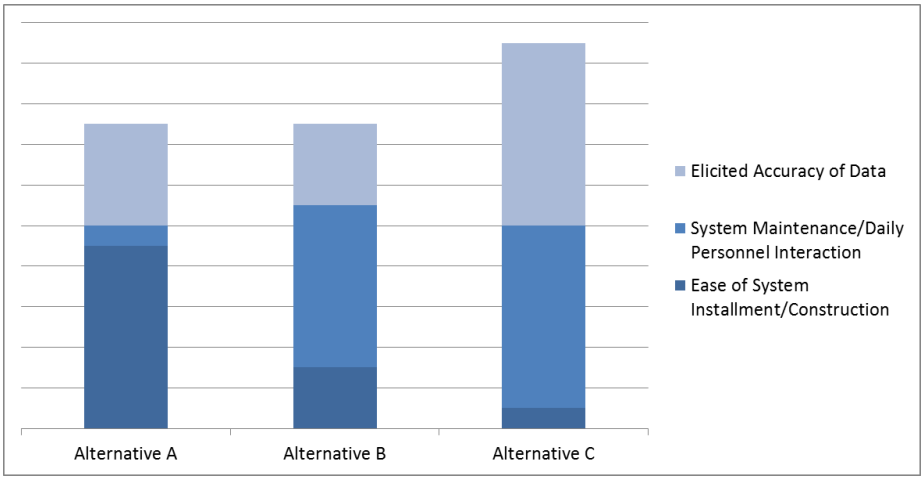

Figure 2 Trade-off analysis of alternatives for eliciting real-time information about active road closures.

2.4.3 Traveler information communication

Considering the data collection method described by Alternative C, the underlying system architecture was developed to enable information relay to Waze. Figure 3 shows the system architecture. This diagram illustrates the procedure, where data from the DDOT database will be transferred to the Waze server. Real-time information about road closures is collected in the DDOT database by means of the application described by Alternative C. Next, the database server queries the active closures from the database, converts each instance to XML format—compatible with the Waze Closure and Incident specifications (details provided in Appendix C)—before transferring the data to the DDOT server. The DDOT server integrates all known closures in to a file (e.g. active_closures.xml) with a pre-authorized path (i.e., enabling password protection) accessible to the Waze Partner Manager. As a content acquisition system, the Waze Partner Manager is responsible for sending the produced xml file to the Waze server when triggered (i.e., when new closure updates are available: new "clock-in" or "clock-out").

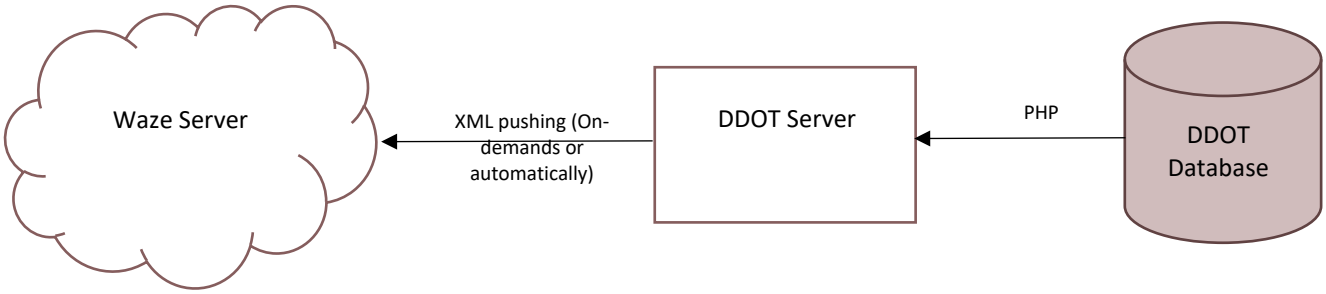

Figure 3 System architecture used to send active closure information to Waze

2.5 System Construction

Cost estimation techniques widely depend on the customer and the problem. Factors such as work limits, extent of available data, data collection methods, agency requirements, hardware specifications, and software development will affect the final estimated cost. Preliminary cost and time estimates for specific tasks are provided in Table 1.

Table 1: Anticipated cost and timeline of solution implementation – system intitalization (Part 1)

Task	Cost Estimate & Task Details	Time Estimate
I. Updating TOPS data fields	• Personnel cost; not a time-intensive procedure with appropriate background	1-2 days
II. Generating Real-Time Reporting Application	• Personnel cost • Internal IT department or hire contractor to generate a mobile/web-based application for collecting real-time information from permit holders • Development focus on ease of use, application appeal, and reliability	7-14 days
III. Development of Database Server & Merging of Appropriate Data Sources	• Personnel cost • Internal IT department or hire contractor to develop a database server • Development of protocol to merge TOPS and real-time application data • Reformatting data into appropriate format for communication with Waze • Transfer data to Waze & perform a series of test cases with Waze personnel to ensure correct functionality • Development of a system monitoring application that triggers alerts when system errors are identified	14-28 days
IV. Evaluating performance of system	• Personnel cost • Periodic checks of system functionality	On-going process

2.6 Operational Example

An operational example is provided in Appendix D. This example details *how* the new form could look, *what* the new form could include, *where* the produced data would be saved, and *how* the data could be merged with existing TOPS data for transmission to Waze.

2.7 System Maintenance

Routine maintenance tasks will be leveraged to ensure the server continues to meet its necessary functionality. A monitoring system will be developed to flag potential system malfunctions and threats at any stage of the system. Another protocol should be developed to periodically check the Waze application to ensure correct and timely dissemination of the information to travelers. Finally, periodic checks to Waze specifications should be performed to ensure smooth compatibility.

2.8 Benefits and Institutional Barriers

Table 2 illustrates the expected benefits of the proposed solution.

Table 2: Anticipated benefits of solution (Part 1)

Operational benefits	• Better informed routing decisions made by Waze & other third-party navigation applications • Better informed decisions by travelers regarding mode & route choice • Better informed decision making by transit & other impacted agencies
Safety benefits	• Greater driver awareness of road closures resulting in greater safety for roadside workers
Mobility benefits	• Reduced demand on corridors with closures • Reduced congestion on corridors with closures
Environmental benefits	• Reduced emissions
Ancillary benefits	• Inter-agency cooperation & data exchange related to closures (e.g., providing warning to local police, secret service, etc. of a scheduled closure or informing VDOT or MDOT of large closures impacting their networks) • Improved methodology for reporting road closure metrics for DDOT accountability measures • Methodology for improving DDOT social media presence, website updates, dynamic message sign alerts, etc.

While the original intention of this component of the solution was to reduce the impact of scheduled road closures by providing better traveler information, many ancillary benefits are achieved through the improved data recording methodologies. The primary barrier to the success of this application is the adoption of the Real-Time Check-in/Check-out Application by permit-holders; without sufficient enforcement of the new procedure in its introductory stages, the full benefits of this system will not be realized. To overcome this barrier, incentives of the new system should be clearly expressed to permit holders, capitalizing on the added safety benefits to workers present on the roadside.

3 Part 2: Operational Strategies Related to Planned Special Events

The second part of the proposed solution addresses the second DDOT objective: incorporating new data sources for improved operational strategies during scheduled special events. The following sections describe the frequent disruptions experienced by the transportation network of the District attributable to special events, which is the underlying motivation for this objective. Next, data sources available to DDOT are investigated to determine their value in planning for improved traffic operations before, during, and after special events. Using the available data sources, a novel methodology is developed that utilizes relevant historic travel data and provides operational recommendations for specific special events. Ideally, the methodology framework will continuously improve over time, as a feedback loop is established to assess the impacts of traffic policy solutions.

3.1 Problem Definition

As an example of the current state of practice for planning for recurring special events, DDOT provided the research team with the 2017 Nationals Park Traffic Operations and Parking Plan (TOPP). The team immediately identified that one of the opportunities for improvement of the Nationals TOPP is to use more recent data for decision-making; the example TOPP used different sets of data (e.g., attendance, traffic sensor data) from the 2013, 2014, and 2015 seasons to make control decisions for the 2017 season. The team hypothesizes that with third-party subscription data services, such as INRIX, new opportunities may exist to use more recent archived data for traffic operations decisions related to planning for recurring special events. Benefits of using more recent traveler behavior data (e.g., 15-min aggregated origin-destination (OD) pairs) include a better understanding of frequently traveled routes for the current season's audience; moreover, using more recent archived data enables the consideration of how the current team is performing, which tends to be highly correlated with attendance. An interview with a DDOT representative revealed that INRIX supplies DDOT with historic data on individual trips (e.g., OD pairs), 15-min average speed data, and 15-min average travel time data (8). As such, DDOT is interested in an innovative solution methodology that uses these data to inform traffic management decisions during repeating special events (e.g., sporting events). This high-level concept-of-operations suggests that during the planning stages for repeating special events, archived data from related events could be queried in an innovative manner and used to inform traffic control decisions. If documented appropriately, this data could then be seamlessly pushed to third-party navigation applications (e.g., Waze) to provide travelers with up-to-date information and promote informed traveler decisions.

3.2 Problem Scope

An interview with a DDOT representative revealed that current TOPP utilizes attendance from past seasons, traffic sensor data, turning movement counts, and DDOT staff empirical observations; in some cases, the data used is as many as five years old. In this same interview, the DDOT representative revealed that DDOT currently subscribes to INRIX data, which includes real-time and archived 15-min aggregated OD, average speed, and average travel time data. This solution seeks to identify an innovative

method to use the newly available INRIX data to supplement the traditional TOPP. While the opportunities to use the INRIX data to improve operations are numerous, the solution presented herein seeks to identify generalizable trends in traveler behavior by innovatively grouping the data before applying it to make decisions regarding traffic control policies.

3.3 User Needs

Considering the stakeholders in Figure 1, the following user needs were identified.

UN 2.1: Understanding of Traveler Behavior

DDOT needs an improved understanding of congestion and traveler behavior trends during/after planned special events to gain situational awareness and improve their response to non-recurring congestion attributable to planned special events.

UN 2.2: Identify Key Mobility Corridors

DDOT needs to identify critical mobility routes during/after planned special events on which to prioritize traffic flow to improve efficiency and reliability of service.

UN 2.3: Minimize Deleterious Impacts to Side Streets and Residential Areas

DDOT needs to improve flow on key mobility corridors to avoid diversion routes by third-party navigation applications.

UN 2.4: Provide Traffic Conditions and Planned Closures/Prohibitions to Travelers

DDOT needs to provide planned lane closures/turn prohibitions to public in a timely fashion to promote improved traveler awareness and optimal decision-making.

UN 2.6: Improve Coordination with WMATA

DDOT needs to identify and prioritize transit routes when determining planned traffic control policy decisions. Moreover, DDOT must coordinate with *WMATA* to improve reliability of transit network after planned special events and encourage modal shifts away from passenger cars.

UN 2.7: Consideration of Pedestrian Traffic

DDOT needs to consider heavy pedestrian paths to transit when defining key mobility corridors and provide separation between key mobility corridors and heavy pedestrian paths to reduce vehicle-pedestrian conflicts.

UN 2.8: Consideration of TNCs and the Department of For-Hire Vehicles

DDOT must identify and enforce pick-up and drop-off locations for taxi and rideshare companies to reduce vehicle conflicts with abruptly stopping vehicles.

UN 2.9: Interagency cooperation and collaboration

DDOT needs to coordinate decisions with other agencies in area (e.g., WMATA, MPD) and local private businesses (e.g., parking garages) to ensure unify approach to non-recurring congestion attributable to planned special events.

3.4 Proposed Solution

The team has proposed a solution that involves using the INRIX 15-min aggregated OD data to identify key corridors on which to prioritize movement, without causing deleterious impacts to transit in the area. <u>The true innovation in the solution is the way in which the data is grouped to identify generalizable trends in traveler behavior after recurring special events</u>. The team proposes the data be grouped by recurring event type (e.g., Nationals games, Capitals games), recurring event start time (e.g., weekday afternoon game, weekday evening game, weekend game), and by recurring event outcome (e.g., significant win/loss, close ending). The team hypothesizes that these three attributes will have an impact on the traveler behavior (e.g., more fans are likely to leave early if the home team is significantly winning/losing compared to a game that is tied).

Once the data is appropriately binned, the team suggests selecting an appropriate starting point (e.g., the last quarter/inning/half of a sporting event) and an appropriate ending point (e.g., 1.5 hours after the end of regulation play), which may be event type specific. For each 15-min period between the starting point and the ending point of interest, the team suggests using the available OD data to identify, at a TAZ level, the top spectator destinations; the optimal routes to these destinations, which are identifiable through time-dependent shortest paths to, are what should be prioritized using appropriate traffic control policies (e.g., turn prohibitions, lane restrictions). Where possible, these key mobility routes should be placed away from major walking corridors to the Navy Yard, Waterfront, and Capitol South Metro stations, to minimize conflicts with pedestrians using transit.

Once key mobility routes are established, they should be cross referenced with major transit routes in the area. If mobility routes and transit routes do not coincide with one another, the agency should consider additional policies to promote mobility on key transit routes. All decisions possibly impacting transit should be coordinated with the region's transit authority. Lastly,

rideshare/taxi pick-up and drop-off areas should be planned in areas adjacent to, but not on, key mobility corridors (e.g., M Street). Surveillance of mobility corridor is necessary to ensure no disruptions are made by taxi/rideshare drivers, with enforcement ready to intervene with increased presence in area if necessary.

Using the 15-min aggregated speed and travel time data from INRIX, DDOT will be able to develop performance metrics to evaluate the selected traffic control policies' performance after the event has ended. The observed behavior for the most recent event will then be added to the appropriate bin of data according to event type, start time, and outcome; lastly, the oldest event data in that bin will be omitted from future analyses, analogous to the way a moving average filter works to smooth trends in time series data.

A flowchart for the proposed methodology is available in Figure 4.

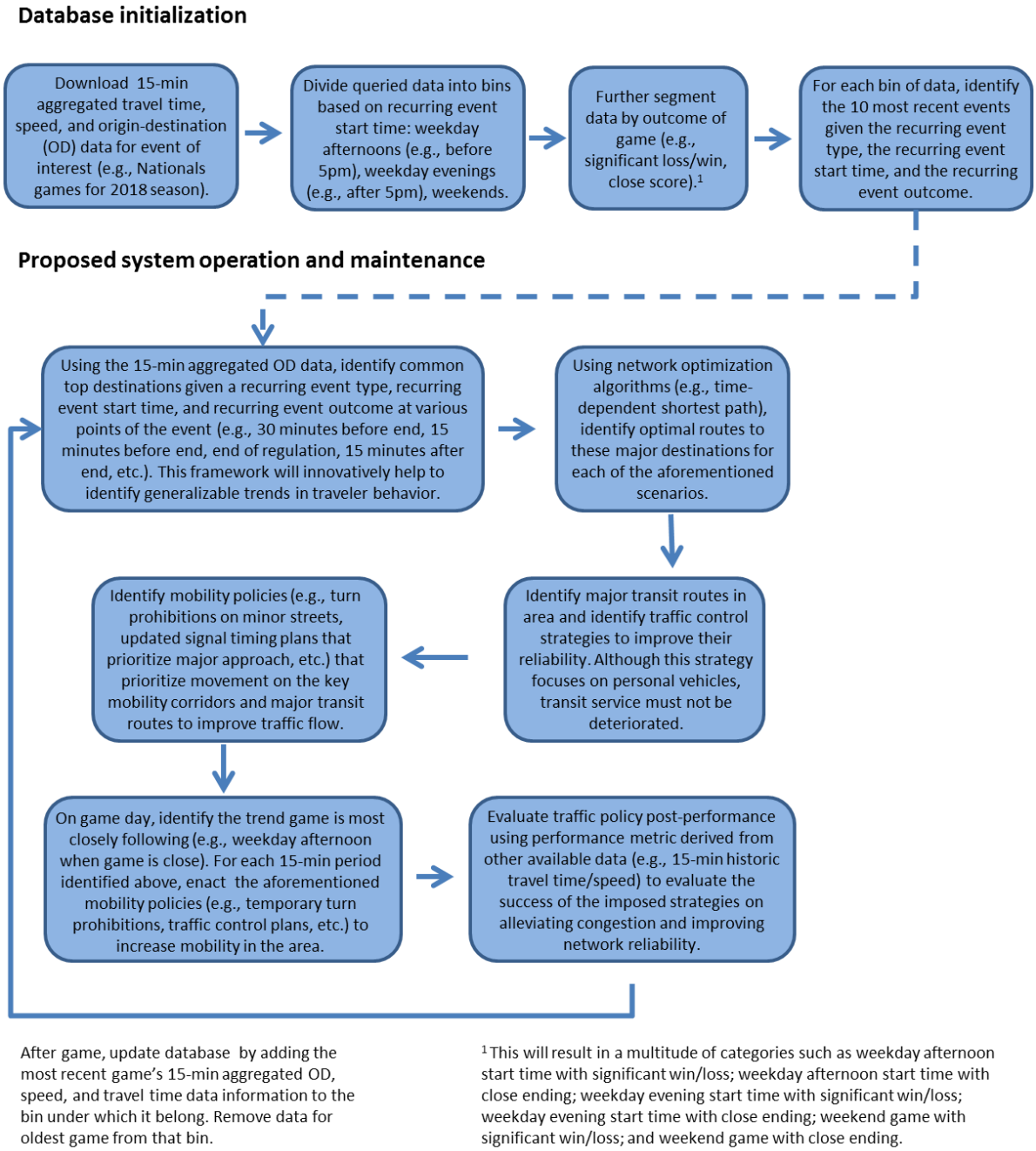

Figure 4: Flowchart of proposed system

3.5 System Construction

Preliminary cost and time estimates for specific tasks are provided in Table 3. Note that the cost and time estimates featured in Table 3 are only for system initialization. However, if the solution is automated appropriately, updating the system (i.e., finding set of top destinations given new data, identifying key mobility corridors, and identifying traffic control policies for each 15-min period of interest) should be straightforward and not burdensome to DDOT.

Table 3: Anticipated cost and timeline of solution implementation – system intitalization (Part 2)

Task	Cost Estimate	Time Estimate
I. Downloading data	• Personnel cost • INRIX data available for free • Cost for maintaining a database ($0 for free alternatives like PostgreSql or ~$100/user/moth for other DBMS vendors)	3-7 days
II. Segmenting the data based on the nature of game day	• Personnel cost for binning historic game data • Consider contracting process out to company with coding experience to automate process	7-14 days
III. Identifying OD pairs	• Personnel cost • Cost significantly lower if OD data available readily available • Consider contracting company with coding experience to automate process	7-14 days
IV. Identifying key mobility corridors	• Personnel cost • If not already available, cost of purchasing TransCAD/VISSUM/other software able to calculate time dependent shortest paths	14-21 days
V. Coordinating with WMATA to accommodate transit and pedestrians	• Personnel cost	3-5 days
VI. Identify mobility policies to achieve goals	• Personnel cost	5-10 days
VII. Evaluating performance of system	• Personnel cost • Consider contracting company with coding experience to automate process	On-going process

3.6 Operational Example

An operational example of this solution during for Nationals games has been omitted for brevity; please see Appendix E for additional detail. Note, though the Appendix features the Nationals Park as the major origin, this solution framework can be expanded to other sporting teams (e.g., Capitals) and other major trip generating events (e.g., concerts).

3.7 System Maintenance

In terms of the data analysis, the system maintenance should be straightforward. Once the system has been initialized, for each planned special event, the most recent event data will be filled in the appropriate bin (i.e., type of sporting event, event start time, event outcome). As new event data are added to a bin, the oldest event data in that bin are omitted from future analyses. Once the new data have been categorized, the time-dependent shortest path will be re-run to identify key mobility routes for the next game that follows that specific trend.

3.8 Benefits and Institutional Barriers

The proposed solution is expected to have numerous benefits to the stakeholders listed in Figure 1, particularly to the traveling public. The anticipated benefits are featured in Table 4.

Table 4: Anticipated benefits of solution (Part 2)

Operational benefits	• Reduced disruptions to side streets/residential areas
Safety benefits	• Reduced pedestrian conflicts by separating key mobility corridors from key pedestrian corridors. • Reduced vehicle conflicts by separating and enforcing rideshare drop-off /pick-up locations away from key mobility corridors
Mobility benefits	• Reduced travel time on key mobility corridors • Increased reliability on key mobility corridors
Environmental benefits	• Reduced emissions
Ancillary benefits	• Improved interagency communication and collaboration

Numerous challenges are also anticipated in the implementation of this solution. The primary challenge is the availability of a staff member with a sufficient data analytics background to initialize and manage the bins of OD data. Secondly, the availability of data, particularly on local streets near the stadium and major post-game destinations, may prove challenging to obtain. Third, it may be difficult to separate congestion directly attributable to the recurring special event versus other factors in a dynamic city like the District; this may bias the results, particularly in the identification of key destinations and in evaluating the performance of the policies implemented on the key mobility corridors. Lastly, this solution requires coordination between multiple agencies including DDOT, MPD, and WMATA; any lack of cooperation between these agencies will diminish the benefits of this solution.

4 Conclusions

This document presents a high-level concept-of-operations for using third-party data applications to improve non-recurring congestion in Washington D.C.. Specifically, this concept-of-operations report presents a two-part solution addressing key objectives identified by DDOT as having greatest influence on their network: (i) improved traveler information related to scheduled road closures and (ii) improved operational strategies during scheduled special events. Each component of the solution is described comprehensively in terms of the problem definition, scope, specific user needs, solution specifications, and perceived impacts.

The first part of the solution involves supplementing the existing District TOPS system with an application that allows permit-holders to "clock-in" and "clock-out", with precise coordinates of their planned work for the day. This refined detail can be automatically pushed to Waze, broadcasted through District variable message signs, and posted on social media in order to enable the public to make better informed travel decisions. The second solution introduces an innovative framework for identifying generalizable trends in traveler behavior at various points of a recurring special event by segmenting the INRIX 15-min binned data by event type, event start time, and expected event outcome. This framework provides DDOT with a method to identify common destinations for spectators, which will then allow DDOT to identify to most critical paths on which to prioritize traffic flow in order to move the most travelers. The high-level architecture for the proposed two-part solution is shown in Figure 5.

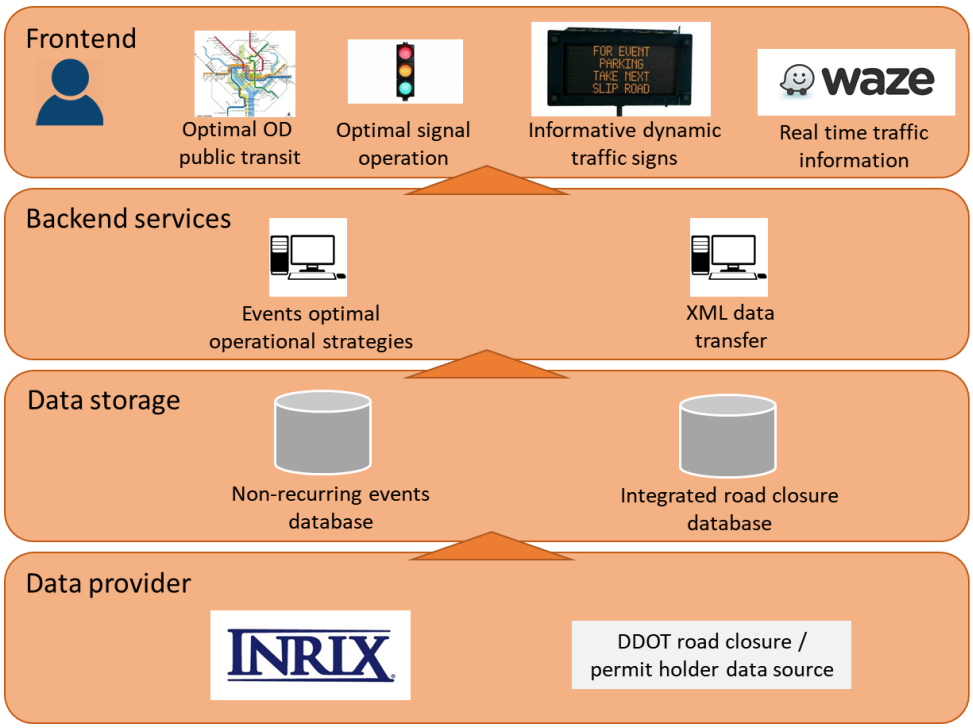

Figure 5: High-level architecture of proposed two-part solution

In conclusion, non-recurring congestion is a problem for many agencies around the country. However, the team believes that with the proposed two-part solution implemented in parallel, these distinct methodologies have the potential to significantly reduce non-recurring congestion in the District.

5 References

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Appendix A: DDOT's Transportation Operations Permitting System (TOPS)

DDOT's TOPS collects the following information from all permit requestors:

- Length of each lane on the road
- Width of each lane of the road
- Latitude/Longitude coordinates
- Permit ID number
- Event Types (Construction Staging Area, City Event, ENP for DDOT Contractors, Mobile Crane Workzone)
- Days left on permit
- When will workers start? (time of day)
- When will workers end? (time of day)

The TOPS interface is shown in Figure A6.

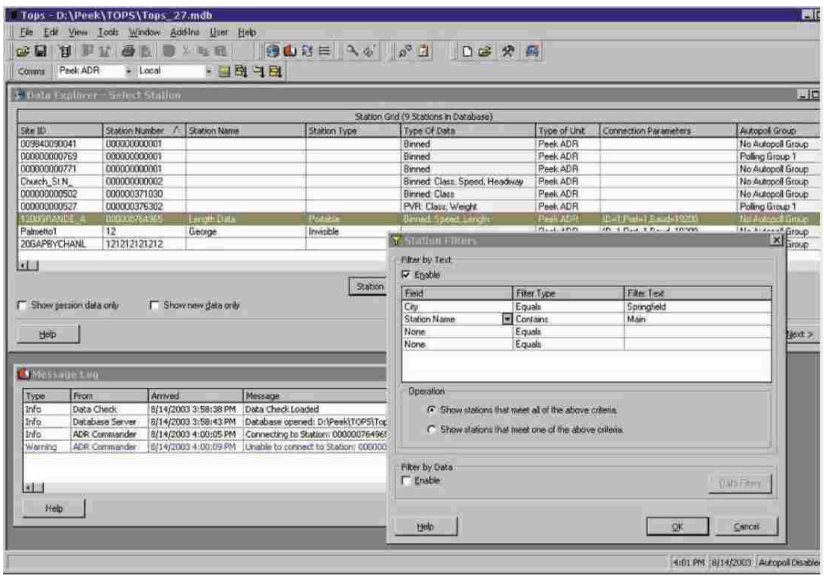

Figure A6: Current TOPS interface (*9*)

This information is aggregated for all permits into a database, as shown in Figure A7.

	A	B	C	D	E	F	G	H	I	J	K
1	**Tracking Number**	**Event Types Code Desc**	**Days Left on Permit**	**Parking Start Time**	**Parking End Time**	**Latitude**	**Longitude**	**TravelLane1Length**	**TravelLane1Width**	**TravelLane2Length**	**TravelLane2Width**
2	1000	Construction Staging Area	15	07:00:00	17:00:00	38.87965857	-77.0083831	200	10		
3	1001	Utilities	31	07:00:00	14:00:00	38.880396133	-77.002763700	590	10	590	10
4	1002	Construction Staging Area	31	07:00:00	18:00:00	38.879988564	-77.001305639	415	10	415	10
5	1003	Block Party	31	12:00:00	18:00:00	38.879742567	-77.002042562	176	10		
6						38.880479002	-77.002051342	56	10		
7	1004	Utilities	31	07:00:00	13:00:00	38.879342791	-76.999635238	168	10		
8						38.879612683	-77.000281899	167	10		
9	1005	Drainage Maintenance	31	07:00:00	18:00:00	38.879564302	-76.997336427	792	10	792	10
10	1006	Construction Staging Area	31	07:00:00	16:00:00	38.878306914	-76.995324319	179	10	179	10
11						38.878488545	-76.995928317	111	10	111	10
12	1007	Construction Staging Area	31	07:00:00	18:00:00	38.878028328	-76.994289078	360	10		
13	1008	Construction Staging Area	23	07:00:00	07:00:00	38.96476221	-77.0324037	280	10		

Figure A7: Sample permit database associated with TOPS

Appendix B: Trade-Off Analysis of Alternatives for Real-Time Road Closure Information Collection

The trade-off analysis presented in Figure 2 was developed using the conditions and relative benefits derived for each alternative, as shown in Table 5. These relative benefits were derived on a scale of 0 to 1, where 0 represents the least benefits and 1 represents the most benefits. In terms of system installment or construction, the simplest system would correspond with Alternative A (phone calls and manual database entry), while the most complex system corresponds with Alternative C (real-time collection of information and automated database entry). System maintenance and daily personnel interaction is opposite: Alternative A presents the lowest benefit, as it is not automated and requires significant interaction from DOT personnel, while Alternatives B & C are automated and therefore require much less daily interaction. Finally, the data accuracy is evaluated for each alternative. Accuracy is defined by the realism of the provided closure times. For Alternative A, DDOT personnel would call the permit holder on the day of proposed work to identify their work times; difficulty in accuracy and reliability for this solution include: (i) not reaching the designated contact person, (ii) talking with a contact person who is not actually on-site with complete information, and (iii) misinterpretation or incorrect data recording. Alternative B requires permit holders to update their work plans for each day via an additional web-based application. While the automated interface for this solution would eliminate misinterpretation and data recording errors, the primary shortcoming is the repetitive nature of this form with the original permit form. If completed, it's likely the same information would be provided by the permit holder as was given during the original permit request. Finally, Alternative C presents the greatest benefits for accuracy. Its automated nature reduces misinterpretation and recoding errors and it overcomes the disadvantages of the repetitiveness of Alternative B. In addition, the precise "clock-in" and "clock-out" times allows an event-triggered protocol for quickly and efficiently communicating the start and end of active road closures with Waze.

Table 5: Real-time data collection system alternatives trade-off analysis – Relative benefit values

Perceived Benefits of Alternatives			
Condition	Alternative A	Alternative B	Alternative C
Ease of System Installment/Construction	0.9	0.3	0.1
System Maintenance/Daily Personnel Interaction	0.1	0.9	0.9
Elicited Accuracy of Data	0.5	0.4	0.9

Appendix C: Waze Data Transmission Specifications

This specification classifies road closure events into basic road closure, enhanced road closure, hazardous closure, and construction closure. Each event contains basic data elements including the location of incident, traffic impact severity, and so forth. An XML sample of a road closure event is illustrated in Figure C8. In this example, the incident ID, its type, the start and end date, type of the event, a description event, its severity, and its location are shown.

```
<event id="unique_id_XFEREF34343">
 <type>CONSTRUCTION</type>
 <subtype></subtype>
 <start_date>2014-07-15T12:00:00-07:00 GMT</start_date>
 <update_date>2014-07-15T12:30:00-07:00 GMT</update_date>
 <end_date>2014-07-25T20:00:00-07:00 GMT</end_date>
 <description>Planned construction in Leon I-10 west at MM</description>
            <severity>MINOR</severity>
 <location>
  <street>I-10 W</street>
                    <city>Miami</city>
  <latitude>30.47872</latitude>
                    <longitude>-84.10985<longitude>
                    <direction>WEST</direction>
                    <specify_end> <!--optional. empty in this case -->
                    </specify_end>
 </location>
</event>
```

Figure C8: An example of a construction road closure in XML format (*10*)

Appendix D: Operational Example of Real-Time Road Closure Communication with Waze

The purpose of this operational example is to illustrate how the proposed system will work in practice.

**Front-end user interfaces*

I. Request permit

The initial permit request is completed using the TOPS as shown in Appendix A, with the added features suggested in Section 2.4.1.

II. Await permit approval

Next, DDOT will use its current procedures to filter through the requested permits and provide approvals to permit holders, when appropriate.

III. Complete Active Road Closure Form

Once approved, the permit holders will be informed of the Active Road Closure Form and instructed to nominate an on-site manager to "clock-in" and "clock-out" on the day(s) with active closures. An example of this form is illustrated in Figure D9. The features of this form should include at a minimum, the original permit number—to reference back to the TOPS database for details about that permit—and the nature of work—checking in or checking out. In addition, if developed on a mobile application, a request for current location (i.e., the physical location of the mobile device used to complete the form) could be incorporated to better define the location of the active closure.

Permit holders will be required to complete this form at least twice a day, when the road closure is started and when it is completed.

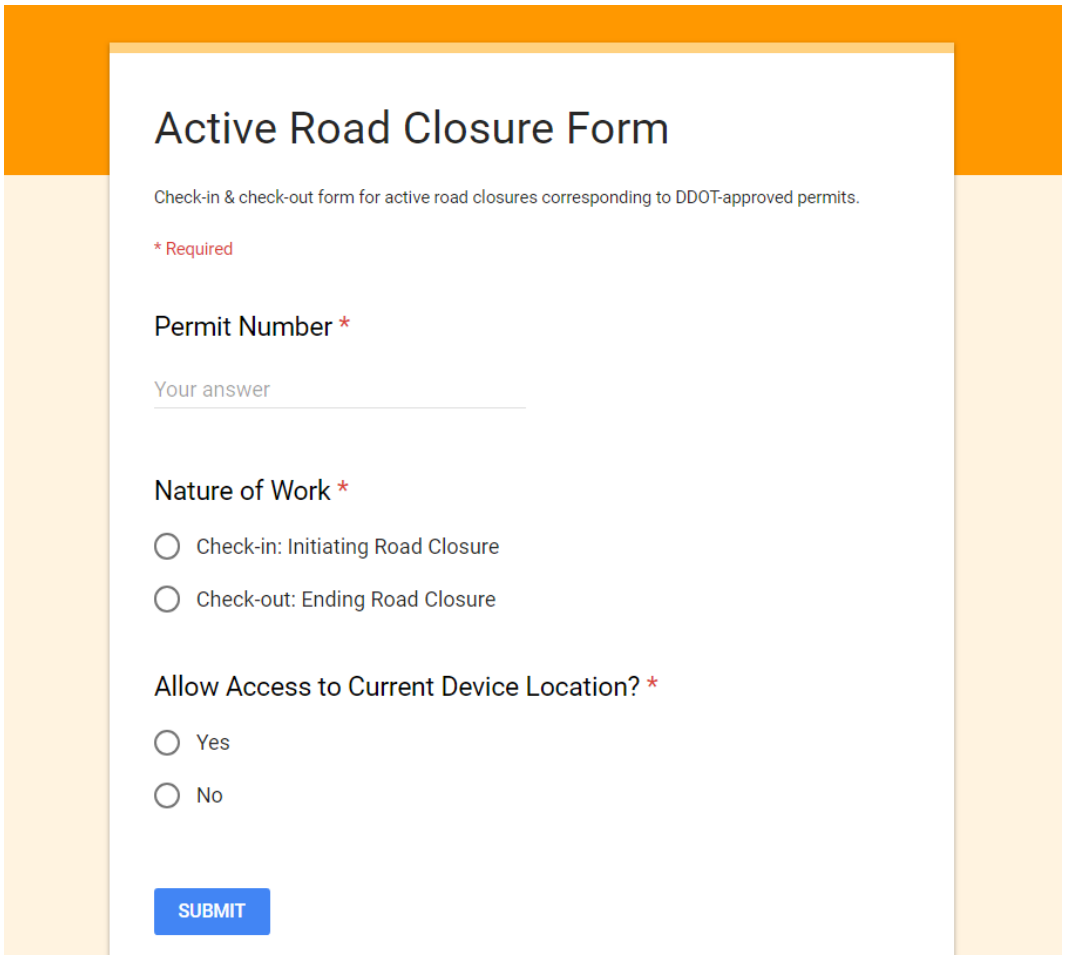

Figure D9: Proof of Concept for Active Road Closure Form

**Back-end protocols*

I. Aggregate information into the DDOT database

Figure D10 shows an example of the Active Road Closure Database. This database will collect all information from authorized permit holders each time they complete the Active Road Closure Form. When available, the location of the mobile device used to complete the form will be stored, along with the current timestamp and all other requested data.

	A	B	C	D	E	F
1	Timestamp	Permit Number	Nature of Work	Allow Access to Current Device Location?	Device Latitude	Device Longitude
2	5/31/2018 12:53:47	1000	Check-in: Initiating Road Closure	Yes	38.950445	-77.146264
3	5/31/2018 12:55:11	1001	Check-in: Initiating Road Closure	Yes	38.898563	-75.152365
4	5/31/2018 12:55:19	1002	Check-in: Initiating Road Closure	Yes	38.777568	-76.565625
5	5/31/2018 12:55:27	1003	Check-in: Initiating Road Closure	No	NA	NA
6	5/31/2018 12:55:37	1006	Check-in: Initiating Road Closure	Yes	38.950445	-77.146264
7	5/31/2018 12:55:45	1002	Check-out: Ending Road Closure	Yes	38.777568	-76.565625
8	5/31/2018 12:55:55	1001	Check-out: Ending Road Closure	Yes	38.898563	-75.152365
9	5/31/2018 12:56:02	1003	Check-out: Ending Road Closure	Yes	38.950445	-77.146264
10	5/31/2018 12:56:48	1006	Check-out: Ending Road Closure	Yes	36.932334	-79.122266
11	5/31/2018 12:56:56	1000	Check-out: Ending Road Closure	Yes	38.950445	-77.146264

Figure D10: Proof of Concept for Active Road Closure Database (ARCD)

II. Database server queries the ARCD & communicates with Waze server

The database server can be set up to query either based on a predefined frequency or event-triggered queries. When using a predefined frequency, the database server queries the ARCD at set intervals. If changes to the ARCD are infrequent, the server can be set up to only query when a change in the database is reported. Based on the Waze CCP specification, the server converts the data from each road closure into XML format to compile the required data elements. It then relocates the XML files to a pre-authorized directory for transfer to the Waze server.

Appendix E: Operational Example of Traffic Control Strategy for Nationals Game

The proposed methodology introduces the opportunity to analyze third-party data, such as INRIX or probe vehicle data available through Waze, to improve special event traffic operations and parking plans (TOPP) by using more recent historical data for planning purposes. The operational scenarios featured in this Appendix are the Nationals baseball games, but this framework can be extended to other recurring planned events, such as concerts. The benefit of this methodology is that it leverages more recent historical data to make TOPP planning decisions, which would not otherwise be considered in a traditional TOPP. The proposed solution methodology for how to leverage recent historical origin-destination (OD) data for planned special events can be summarized in the following steps.

I. Download the historic travel time and OD demand data in the region of interest

The Probe Data Analytics Suite interface available for INRIX data offers several tools to download the data and analyze trends (shown in Figure E11). The interface provides useful information to obtain general traffic trends. Features like congestion scan and trend map can be used to identify the variation of congestion level on each link in the network. However, the analysis recommended herein should be completed using exported raw data, also available on the INRIX interface.

Figure E11: Probe Data Analytics Suite Interface

It is recommended that travel time and origin-destination (OD) data for previous sporting events that season (e.g., all 2018 Nationals games; all 2018 Capitals games) be downloaded from the Probe Data Analytics Suite interface. For games early in the season, it is suggested to query the previous season's data to ensure sufficient data for decision-making. As described later in this section, the oldest event data will be replaced after each new event with available data, so the previous season's data will eventually be replaced with more recent data. The team recommends using the 15-min aggregated origin-destination (OD) data, which was revealed as an available source of data in an interview with DDOT's Kelli Raboy; however, that data was unavailable to the team for this operational example; **as such, the remainder of this section will be written using travel time data as a surrogate for the recommended OD data.**

The massive data downloader within the Probe Data Analytics Suite (top right option in Figure E11) is used to download the data; an area of interest surrounding the stadium location is selected using the "Map" tab under "Select roads". This is shown in Figure E12, where travel time data on links surrounding the Washington Nationals Park are illustrated. When selecting the boundary, it is appropriate to be conservative by choosing a large area; this area will be refined using the extracted data. The exported travel time data is shown in Figure E13. It is worthy of note that one should only use data with a high confidence value (i.e., a corresponding score of 30 or higher); a score less than 30 implies that the reported travel time is based on historical information that does not necessarily reflect game day conditions.

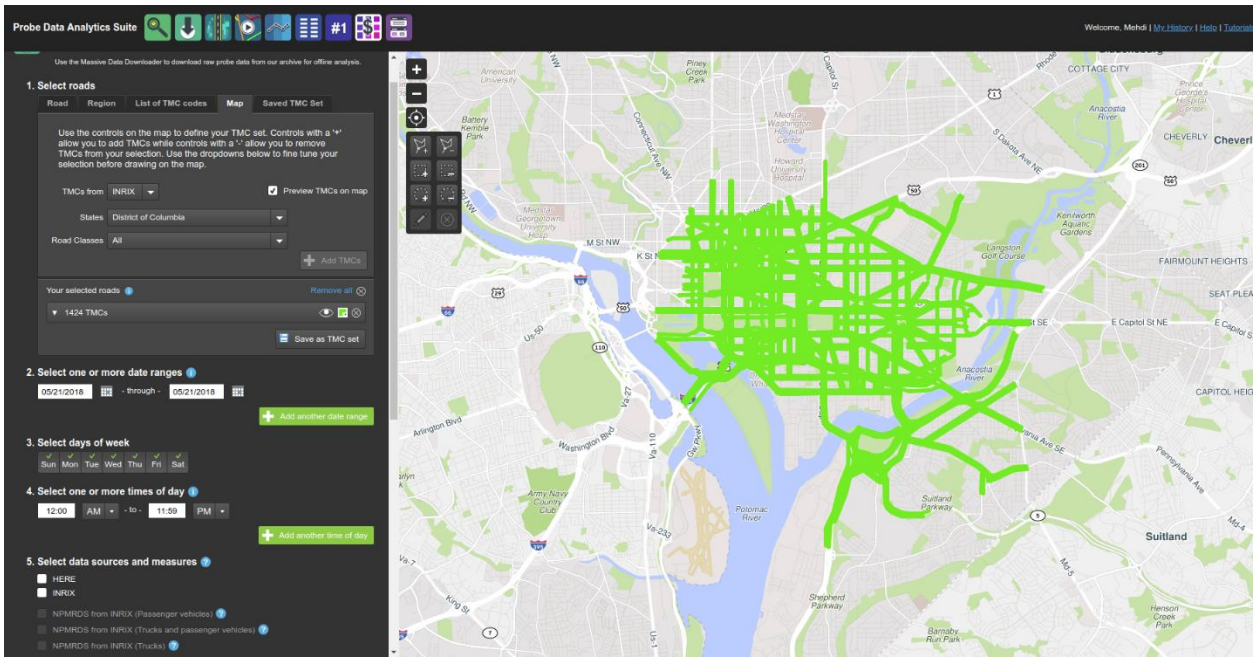

Figure E12 Interface for downloading the raw data

A1 | tmc_code

	A	B	C	D	E	F	G	H
1	tmc_code	measurement_tstamp	speed	average_speed	reference_speed	travel_time_seconds	confidence_score	cvalue
2	110-10140	2018-04-01 00:00:00	15	12	12	36.94	30	96.7
3	110-10140	2018-04-01 00:10:00	13.5	12	12	41.06	28	96.44
4	110-10140	2018-04-01 00:20:00	12	12	12	46.18	30	96.2
5	110-10140	2018-04-01 00:30:00	11.28	12	12	49.12	28	96
6	110-10140	2018-04-01 00:40:00	12	12	12	46.18	10	
7	110-10140	2018-04-01 00:50:00	16.02	12	12	34.58	22	50.67
8	110-10140	2018-04-01 01:00:00	18.69	12	12	29.65	30	73.6
9	110-10140	2018-04-01 01:10:00	18	12	12	30.79	30	97.7
10	110-10140	2018-04-01 01:20:00	12	12	12	46.18	10	
11	110-10140	2018-04-01 01:30:00	12	12	12	46.18	10	
12	110-10140	2018-04-01 01:40:00	12	12	12	46.18	10	
13	110-10140	2018-04-01 01:50:00	9.8	12	12	56.57	22	48.33
14	110-10140	2018-04-01 02:00:00	8.22	12	12	67.38	30	88.2
15	110-10140	2018-04-01 02:10:00	11.38	12	12	48.7	22	93.83
16	110-10140	2018-04-01 02:20:00	11.19	12	12	49.54	28	95.44
17	110-10140	2018-04-01 02:30:00	11	12	12	50.38	30	97.7
18	110-10140	2018-04-01 02:40:00	11.68	12	12	47.44	16	98
19	110-10140	2018-04-01 02:50:00	12	12	12	46.18	10	
20	110-10140	2018-04-01 03:00:00	12	12	12	46.18	10	

Figure E13: Screenshot of raw data export from Probe Data Analytics Suite interface

II. Segmentation of data based on the nature of recurring special event (i.e., event time, start time, and anticipated outcome)

The key contribution of this methodology is in its innovative binning of the data to identify generalizable trends in travel behavior. First, the data is segmented based on the start time of the recurring special event. These categories may include, but are not limited to, weekday afternoons, weekday evenings, and weekends. This captures the fact that spectators that attend multiple games a year are likely to attend games at that same start time (e.g., someone with a standard 9-5 job likely does not frequently attend a game beginning at 1pm on a weekday).

Next, the data is divided based on the outcome of game (e.g., significant loss/win, close ending). The suggested categories include the following:

a. Weekday afternoon start time with significant win/ loss

b. Weekday afternoon start time with close ending
c. Weekday evening start time with significant win/ loss
d. Weekday evening start time with close ending
e. Weekend game with significant win/ loss
f. Weekend game with close ending

The second segmentation hypothesizes that there may be significant difference in travel demand and travel pattern based on the expected outcome of the game (e.g., more spectators are likely to leave 15-min before the end of regulation play if the team is significantly winning/losing rather than a tied game). Lastly, the data is separated based on the relative importance of the game (e.g., regular season, playoffs).

III. Identification of time-dependent critical spectator destinations during/after end of regulation play

To explore time-dependent trends in traveler behavior, the differences in spectator destination choices are explored for 15-min bins of data. The team suggests selecting an appropriate starting point (e.g., the last quarter/inning/half of a sporting event) and an appropriate ending point (e.g., 1.5 hours after the end of regulation play), which may be an event type specific decision. An example of this segmentation given an analysis starting point and ending point can be observed in Figure E14.

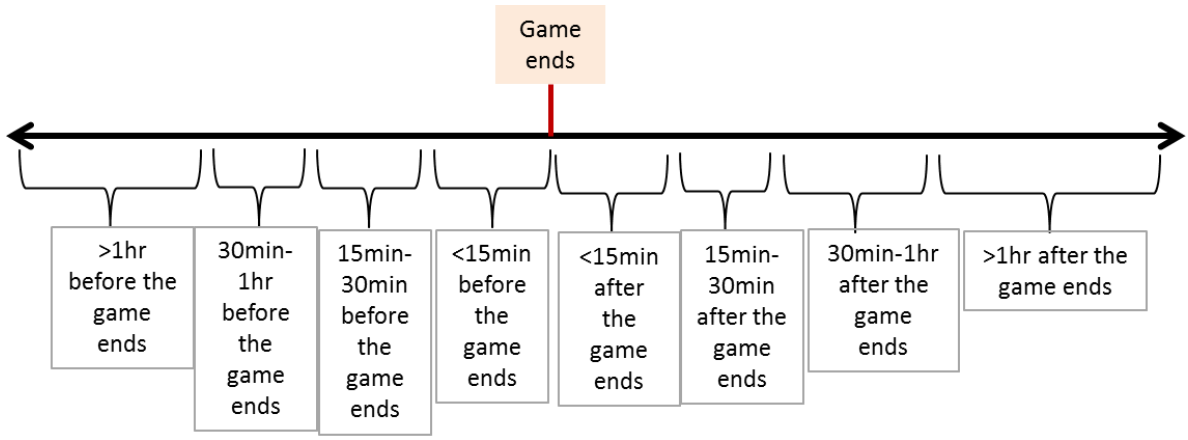

Figure E14: Example sporting event timeline for separate binned data analysis

Next, for each category of data (i.e., event type, starting time, and expected outcome) and aggregated time period before/after end of regulation time (see Figure E14), the most common spectator destinations are identified at a TAZ level. This should be fairly straightforward given the availability of 15-min OD data to the agency. Simply, identify the X (e.g., 5) historically most popular destinations for event spectators for each time period of interest. However, if the OD data is unavailable or unreliable, the most popular destinations can be inferred from the travel time data by looking for links experiencing higher than normal congestion levels: if the event day travel time is higher than the average travel time by a certain percentage threshold (which can be calibrated based on experience), the link is included in the "zone of influence". This zone features the links that are most significantly impacted as a result of the recurring special events; the zone of influence will help identify the locations where re-routing or improved traffic plans may have a positive impact.

There are two possible methods for determining the zone of influence. The first option is using geographic information system (GIS) software of choice. The shape files for the area can be exported alongside travel time data through INRIX. After creating the network in GIS, the historical and extracted travel time data can be input as attributes to the corresponding links. This is shown in Figure B15. After that, the user may query the data to identify differences between historic and binned game day data using the tools provided in a GIS software. By identifying links that have a significant difference between historical and binned game day travel times, the "zone of influence" can be flagged as the region within which the added delay exceeds a certain threshold. The team recommends this be completed for the different time periods of interest before/after the end of the game such that time-dependent congestion mitigation policies can be implemented.

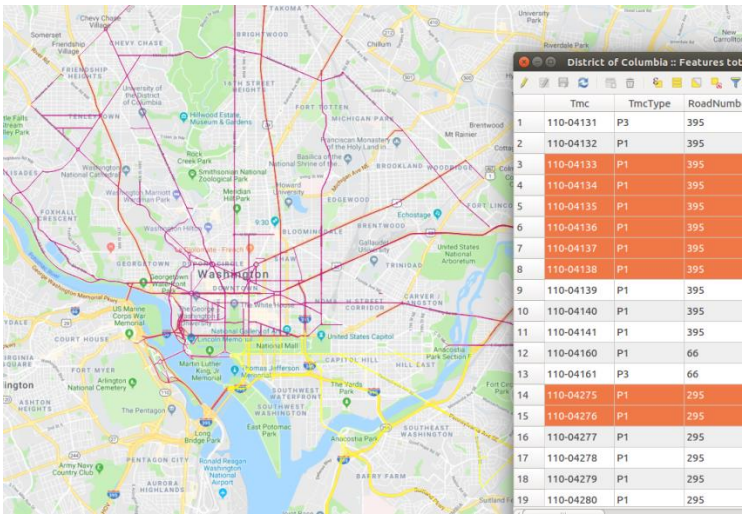

Figure B15: Comparative analysis of travel times using GIS software

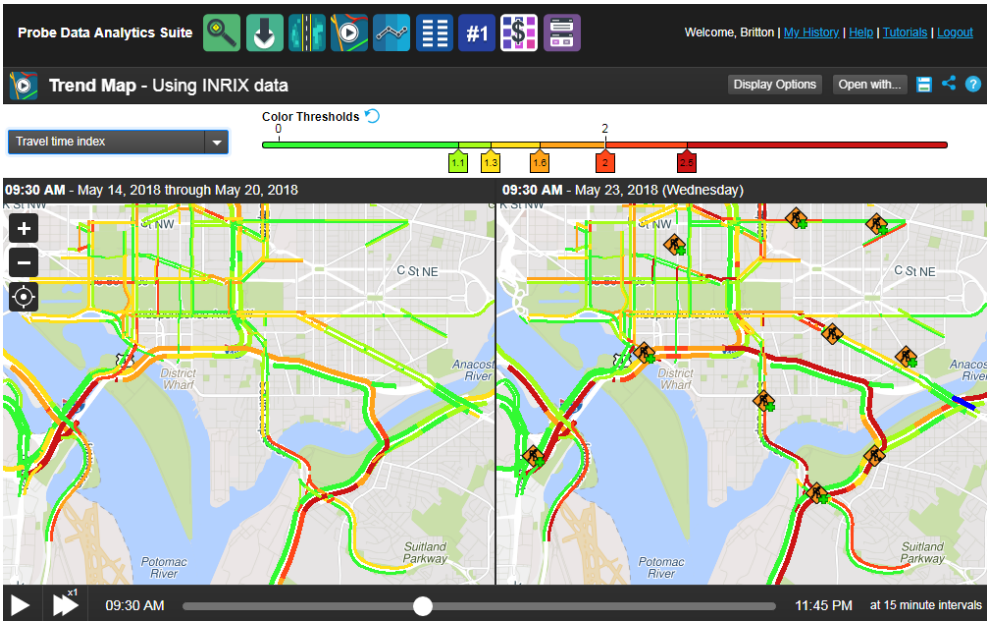

Figure E16: Comparative analysis of travel times using the Probe Vehicle Data Analytics Suite interface

If the agency lacks the GIS software required for the aforementioned analysis, other tools available through the Probe Vehicle Data Analytics Suite interface may serve as sufficient surrogates. Figure E16 shows the comparison of traffic trends thirty minutes before a Nationals game on May 23rd against general traffic trends over the last two weeks in May 2018. In Figure B6, links belonging within the zone of influence become apparent without GIS software. Moreover, the approximate locations of critical destinations can be inferred by looking at the end points of overly congested paths.

The origin of the trips will all be at the park/arena of interest. This can either be aggregated (at a TAZ level) or more discretized around the park (e.g., using parking garages in the region as trip generators). As an example, the locations of parking garages adjacent to the National's Park are pictured in Figure E17 alongside parking rates and hours.

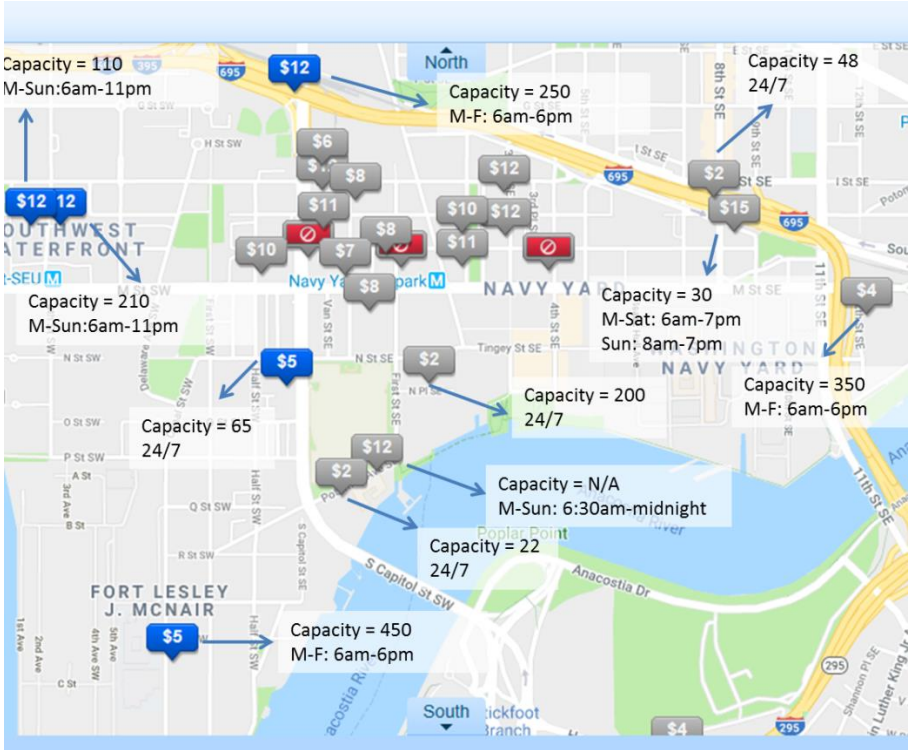

Figure E17 Parking garage location and parking rates near Nationals Park, DC

IV. Identification of key mobility routes

Once the top destinations for spectators are identified—either directly, through available OD data, or indirectly, through analysis of travel time trends—for each period of interest, the historical travel time binned data can be used to construct time-dependent shortest paths connecting the origin to the top identified destinations. The objective for the shortest path calculations can be set based on the quantity of interest such as minimizing travel time, minimizing stopped delay, or maximizing reliability.

The new optimal routes derived from using the time-dependent shortest path algorithm provide the agency with the routes that will be primarily considered by most travelers while trying to leave the park for the 15-min period of interest. These are deemed the "key mobility routes" for that specific time period and are the routes on which traffic flow should be prioritized to efficiently service the most travelers. Where possible, these key mobility routes placed away from major walking corridors to the Navy Yard, Waterfront, and Capitol South Metro stations to minimize possible vehicle-pedestrian conflicts.

V. Consideration of alternative modes

Once key mobility routes are established, they should be cross referenced with major transit routes in the area. If mobility routes and transit routes do not coincide with one another, the agency should consider additional policies to promote mobility on key transit routes. All decisions possibly impacting transit should be coordinated with the region's transit authority. Lastly, rideshare/taxi pick-up and drop-off areas should be planned in areas adjacent to key mobility corridors (e.g., M Street). The 2017 TOPP recommends pick-up locations of Half Street SE between M and L streets and the west curb of New Jersey Avenue SE between M and Tingey Streets for taxi and TNCs, respectively; the recommended drop-off locations are the north curb of M Street SE in front of the Lerner Building and the west curb of New Jersey Avenue between M and Tingey Streets for taxis and TNCs, respectively. The team sees no reason to initially suggest deviations from the status quo, so long as these streets are not designated as key mobility corridors. Surveillance of mobility corridor is necessary to ensure no disruptions are made by taxi/rideshare drivers, with enforcement ready to intervene with increased presence in area if necessary.

VI. Identify existing mobility policies to prioritize traffic on key mobility and transit routes

Next, mobility policies are identified for possible application during each 15-min period of interest. These include, but are not limited to, turn prohibitions on minor streets, no left turns at certain intersections, and updated signal timing plans prioritizing designated key corridor movements. These policies should be evaluated and prioritized for implementation in terms of their effectiveness maintaining/increasing mobility on the key mobility and transit routes.

VII. Implement time-dependent mobility policy on game day according to event start time, expected event outcome, and 15-min period of interest relationship to end of regulation play

On game day, when the solution is set to go active, the game should be classified as "likely significant win/loss" or "close ending" prior to the first period of interest. The agency should then begin implementing the planned traffic policies to promote traffic flow. Planned traffic management policies (e.g., lane closures, left lane prohibitions, etc.) should be broadcast to the public via third-party navigation applications (e.g., Waze through the Connected Citizen Program), through dynamic message signs located throughout the city, and through social media.

VIII. Evaluate post game performance

The agency should develop performance metrics using 15-min historical travel time and speed data to determine how effective strategy was at improving mobility during/after the planned special event. The agency should evaluate the traffic policy post-performance using aforementioned performance metric to determine if using OD information to inform decisions has improved performance compared to the "before" period.

IX. Add most recent game's data to appropriate bin; remove oldest game's data from future analyses

After the game has ended, the observed behavior for the most recent event will then be added to the appropriate bin of data according to event type, start time, and outcome; moreover, the oldest event data in that bin will be omitted from future analyses, analogous to the way a moving average filter works to smooth trends in time series data.