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Assessment of the Richmond District's Towing and Recovery Incentive Program (TRIP) Pilot

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Abstract:

On December 15, 2017, the Virginia Department of Transportation's Richmond District began a towing and recovery incentive program (TRIP) pilot where tow companies receive a monetary bonus for clearing commercial vehicle crashes within 90 minutes. TRIP's key objective is the facilitation of quick and safe clearance of commercial vehicle crashes through improved towing standards, procedures, and training.

The purpose of this study was to evaluate the effectiveness of the TRIP pilot in terms of clearing commercial vehicle crashes from roadways in the Richmond District more quickly and efficiently than in the before pilot period. The analysis period was 3 years before the pilot (December 15, 2014, to December 14, 2017) and 1 year after the pilot was initiated (December 15, 2017, to December 14, 2018). The scope of the study involved understanding and refining performance measures, data needs and availability, and analysis methodologies. The following tasks were performed to achieve the study objectives: (1) determine evaluation metrics and identify datasets and data sources, (2) collect and filter incident data, (3) compute and analyze evaluation metrics, and (4) perform a qualitative assessment.

The results showed that when the top 61 incidents in the before period vs. TRIP incidents were analyzed, the average roadway clearance time (RCT) showed a statistically significant improvement of 62 minutes per TRIP activation and the average towing response time (TRT) improved by 7 minutes per TRIP activation. When the top 39 incidents in the before period vs. the after period were analyzed, the average RCT improved by 50 minutes per TRIP activation and the average TRT improved by 6 minutes per TRIP activation. Based on these two filtering methods, the benefits of TRIP were found to outweigh the costs by a factor of 9.2 (top 61 approach) to 12.0 (top 39 approach) over a 10-year operational horizon. When cargo spill incidents were analyzed, the RCT improved by 96 minutes when comparing before vs. TRIP only incidents and 110 minutes when comparing before vs. all after incidents; however, low sample sizes and high data variability prevented inferences with regard to statistical significance. As evidenced by responses to interview questions, both the Virginia State Police and towing vendors viewed the program favorably. The Virginia State Police witnessed more professional towing operations and more timely removal of high impact, heavy vehicle crashes. The towing vendors thought that the culture of the towing community has changed in terms of the expedited response and clearance protocols for both TRIP and non-TRIP incidents.

Based on the results, the study concluded that (1) the TRIP pilot showed promising results, (2) the TRIP program was viewed as a success by primary stakeholders, and (3) the TRIP development and operational management were successes. The study recommended that the Virginia Department of Transportation (1) continue TRIP operations in the Richmond District and explore opportunities to expand the program to other districts in Virginia, and (2) conduct ongoing performance analyses of TRIP and begin collecting critical incident timestamps such as tower dispatch and tower response in all districts.

FINAL REPORT

ASSESSMENT OF THE RICHMOND DISTRICT'S TOWING AND RECOVERY INCENTIVE PROGRAM (TRIP) PILOT

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Virginia Transportation Research Council
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ABSTRACT

On December 15, 2017, the Virginia Department of Transportation's Richmond District began a towing and recovery incentive program (TRIP) pilot where tow companies receive a monetary bonus for clearing commercial vehicle crashes within 90 minutes. TRIP's key objective is the facilitation of quick and safe clearance of commercial vehicle crashes through improved towing standards, procedures, and training.

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Based on the results, the study concluded that (1) the TRIP pilot showed promising results, (2) the TRIP program was viewed as a success by primary stakeholders, and (3) the TRIP development and operational management were successes. The study recommended that the Virginia Department of Transportation (1) continue TRIP operations in the Richmond District and explore opportunities to expand the program to other districts in Virginia, and (2) conduct ongoing performance analyses of TRIP and begin collecting critical incident timestamps such as tower dispatch and tower response in all districts.

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INTRODUCTION

The economic impacts of congestion are clear and have been documented in numerous publications, most recently in the 2019 Urban Mobility Report[1] in which the total financial cost of congestion in the United States in 2017 was reported to be $166 billion, or $1,010 per commuter. Improving traffic incident management (TIM) is one way to reduce congestion, as traffic incidents account for approximately 25 percent of total congestion on U.S. highways[2] and in the range of 10 to 60 percent across Virginia Department of Transportation (VDOT) districts.[3] TIM combines public safety and traffic management functions to help reduce the detection, response, and clearance times of incidents on roadways. The Federal Highway Administration continues to support and champion laws, policies, and practices that speed up the clearance of major and minor incidents. The benefits of reduced incident duration through effective TIM programs have also been well documented. For example, studies show that secondary crashes attributable to congestion caused by a previous traffic incident are estimated to represent 20 percent of all crashes and that the likelihood of a secondary crash increases 2.8 percent for each minute the primary accident continues to be a hazard.[4]

VDOT's mission is to "plan, deliver, operate and maintain a transportation system that is safe, enables easy movement of people and goods, enhances the economy and improves our quality of life." One of the goals in pursuing the mission is to operate the system efficiently, which includes implementing incident management solutions. In support of VDOT's mission and goals, in a 2016 study from the Virginia Transportation Research Council (VTRC), Dougald et al.[5] investigated TIM initiatives, including quick clearance policies and practices used by other state departments of transportation (DOTs) to (1) determine the advantages and disadvantages of these initiatives, and (2) assess the feasibility of adopting strategies that are not currently implemented in Virginia. The first recommendation in the report[5] was that VDOT's Operations Division and regions implement one or more of the four pilot projects developed in the study:

1. towing and recovery incentive programs
2. zone-based towing
3. emergency relocation
4. rural incident response teams.

The purpose of the "pilot" designation was to help facilitate the initiation of quick clearance strategies not currently used in Virginia within a short timeframe.

The second recommendation in the report was that VTRC assist in evaluating the pilot projects to include "before and after" studies of incident durations and clearance time comparisions. As part of an implementation effort, VDOT's Operation Division and the Statewide TIM Committee authorized the intiation of two pilots for VDOT's Staunton Distict: (1) emergency relocation (referred to as "contract towing"), and (2) rural incident response teams. In a 2017 VTRC study, Dougald and Venkatanarayana[6] evaluated the two pilots and found that contract towing operations reduced average lane clearance time, queue dissipation time, and delay costs while increasing average incident duration and regain time. Conclusions regarding the effectiveness of the contract towing pilot could not be determined because all results were statistically insignificant because of small sample sizes. However, rural incident response operations resulted in statistically signicant reductions in average lane clearance time and incident duration, thereby providing conclusive evidence of the effectiveness of the first responder pilot.

On December 15, 2017, VDOT's Richmond District, with consulting support by Parsons, began a towing and recovery incentive program (TRIP) pilot where tow companies receive a monetary bonus for clearing commercial vehicle crashes within 90 minutes. TRIP's key objective is the facilitation of quick and safe clearance of commercial vehicle crashes through improved towing standards, procedures, and training. Richmond's TRIP pilot was developed with similar operating characteristics and protocols as incentive programs developed and implemented with success in Georgia,[7] Florida,[8] and Ohio.[9] To be eligible to participate in the program, tow companies had to meet certain equipment, training, and inspection requirements that are detailed in the Richmond TRIP specifications and application document.[10] In order to be rewarded with a monetary bonus of $2,500, TRIP towers must respond to incidents within 45 minutes during peak hours or 60 minutes during off-peak hours; further, upon notice-to-proceed (NTP) directives, TRIP towers must clear vehicles from the roadway within 90 minutes. In cases where extra equipment is required, an additional $1,000 is awarded. The TRIP incident activation criteria (vehicle classes and incident types) are shown in Appendix A, and the activation procedure flow chart is shown in Appendix B.

Figure 1 shows the boundaries of the TRIP pilot, which was limited to interstates in the Richmond District, including I-95, I-64, I-295, I-85, and I-195. The total centerline miles covered from TRIP operations in the Richmond area was 196.4 miles. Table 1 shows the specific mile markers on each interstate. Towing companies that qualified for and participated in TRIP engaged in response and recovery of high impact heavy vehicle incidents within predetermined zones.

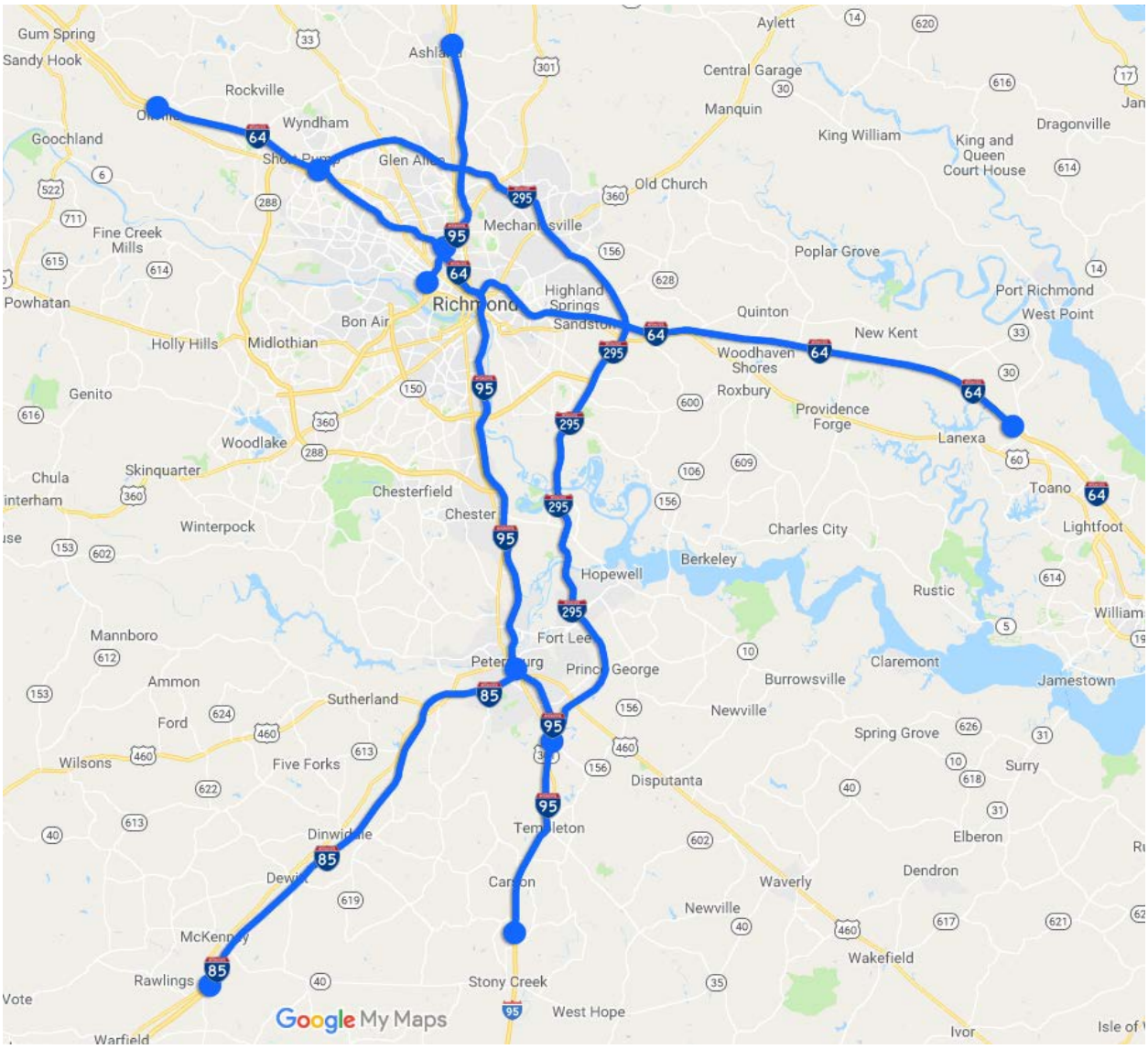

Figure 1. TRIP Interstate Segments in VDOT's Richmond District. TRIP = towing and recovery incentive program.

Table 1. Details of TRIP Interstate Segments in VDOT's Richmond District

Interstate	Boundaries (Mile Markers)	Centerline Miles
I-95 (Overlap of I-95 and I-64)	34.7-92.0 (187.31 to 190.86 on I-64)	57.30 (3.55)
I-64	167.0-225.0	58.00
I-295	0-52.75	52.75
I-85	40.2-68.6	28.40
I-195	0-3.5	3.50
Total		196.40

TRIP = towing and recovery incentive program.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the effectiveness of the TRIP pilot in terms of clearing commercial vehicle crashes from roadways in the Richmond District more quickly and efficiently than in the before pilot period. The analysis period was 3 years before the pilot (December 15, 2014, to December 14, 2017) and 1 year after the pilot was initiated (December 15, 2017, to December 14, 2018). The scope of the study involved understanding and refining performance measures, data needs and availability, and analysis methodologies.

METHODS

The following tasks were performed to achieve the study objectives:

1. Determine evaluation metrics and identify datasets and data sources.
2. Collect and filter incident data.
3. Compute and analyze evaluation metrics.
4. Perform a qualitative assessment of TRIP implementation.

Task 1: Determine Evaluation Metrics and Identify Datasets and Data Sources

Evaluation Metrics

Figure 2 shows a typical roadway incident timeline from T_0 = incident occurs to T_7 = normal traffic flow returns. TRIP's primary objectives with respect to the timeline are to improve (1) response time (T_2 to T_4) by towers, and (2) roadway clearance time (T_1 to T_5). Therefore, towing response time (TRT) and roadway clearance time (RCT) were deemed the primary evaluation metrics for comparative analyses of before and after data, with a higher emphasis on RCT as it directly impacts motorist benefits.

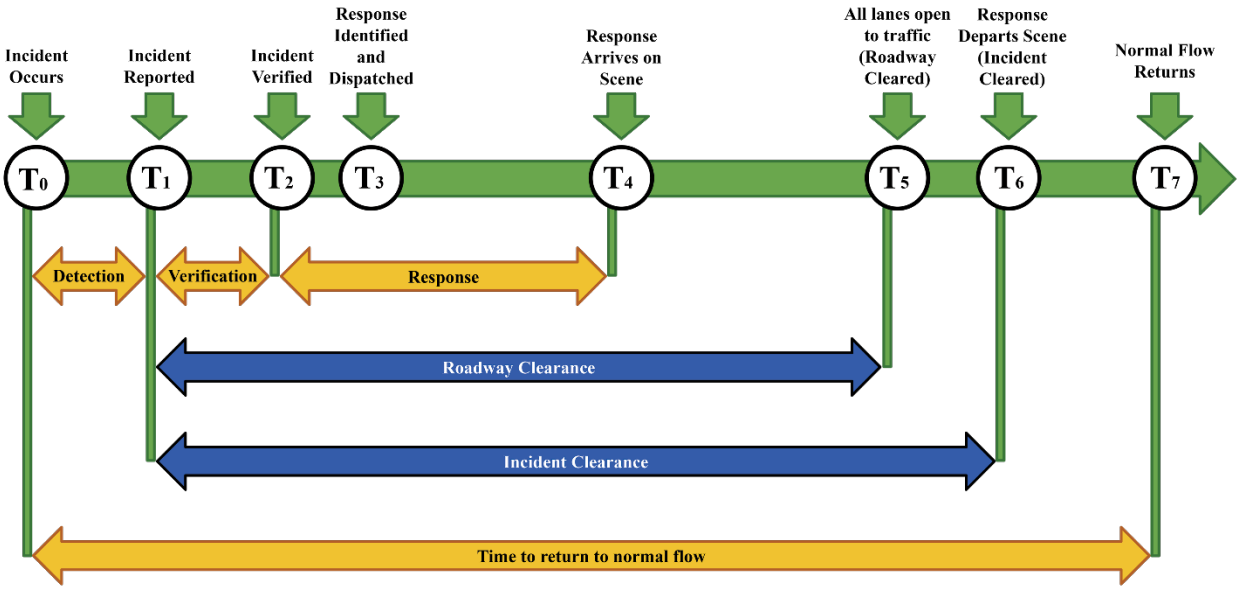

Figure 2. Traffic Incident Management Timeline. Adapted from Conklin et al.[11]

In this report, RCT is defined as the time from the start of the incident (T_1 and T_2 are considered similar for practical purposes) to the time that all travel lanes are open to traffic (T_5). RCT was calculated for all lane-impacting incidents, whether the lane was closed by the crash or for response activities. If a lane-blocking incident was converted to a shoulder event and cleared later as a scheduled work zone and the work zone involved closing a lane, this additional lane closure is not included in the RCT.

TRT is measured from the start of the incident (i.e., T_1) to the recorded arrival of the first tower/wrecker to the incident scene (T_4). Several benefit/cost (B/C) ratios of TRIP were developed by monetizing the RCT benefits, by considering different time horizons for annualizing the pilot's capital costs, and by removing one or more incidents in different time periods to conduct sensitivity analyses.

Additional performance measures deemed appropriate to evaluate TRIP and considered for this evaluation but not calculated because of data limitations included the following:

- *TRIP activation time:* the time period from the start of the incident (T_1) to when TRIP was activated. This is an important metric for internal evaluation of program efficiency and monitoring of trends over time.

- *Notice-to-proceed (NTP):* the timestamp when towers are given the incident scene for vehicle recovery. As a time period, NTP refers to the time from tower response to the scene to when they were given NTP. This is also an internal evaluation metric and is often not known in the before period.

- *Vehicle hours of delay (VHD) and queue lengths:* delay is the direct time loss suffered by motorists as a result of the incident and its clearance period. Motorist delays and their monetized delay costs are two additional measures of great interest to a

transportation agency and are useful for calculating a B/C ratio for the program. Traffic volume and travel time or speed data are needed to estimate queue lengths and VHD. Ideally, these delays should be estimated or calculated for both the mainline and the detour routes.

- *Secondary crashes:* the crashes that are an indirect result of another crash or incident. Reduction of secondary crashes is an important benefit for both the responder community and motorists. Quick clearance of incidents protects both groups by reducing exposure to potential secondary crashes. RCT, queue length, and motorist delay also serve as surrogate measures for secondary crashes.

- *Queue dissipation time:* the amount of time from the start of an incident (T_1) to when the queue fully dissipates (a variation of T_7), i.e., the average traffic speed is within 5 mph of the historic average speed for that time of day and day of week.

- *Regain time:* the amount of time from the start of an incident (T_1) to when the average traffic speed at the incident scene returns to within 5 mph of the historic average speed for that time of day and day of week (a variation of T_7).

Trip activation time, NTP, TRT, and RCT are critical, inherent components of TRIP, and TRIP logs document these timestamps in the after period. Since TRIP data are not available in the before period, both the TRIP activation time and the NTP are not meaningful metrics for a before-after evaluation. Incident logs maintained by a transportation or state patrol agency are often the primary data sources for these timestamps. Although all of the commercial vehicle crashes considered for TRIP activation are likely large enough to warrant police reporting and recording, police reports are not designed to capture lane closure activity, timestamp of traffic restoration, or queue lengths. Police reports are useful to verify the primary incident logs.

VHD is associated with T_7 in Figure 2 and can be used for TRIP B/C analyses; however, this study identified several data and methodological concerns with direct VHD calculation that rendered the measure unusable.

The Regional Integrated Transportation Information System (RITIS)[12] has a module that calculates user delay in vehicle hours and also as costs, using national average traffic volume profiles, annual average daily traffic (AADT), percentage of trucks in the traffic, and national average hourly rates for passenger cars and trucks. Although these values are deemed quite reasonable as average values, RITIS cautions that the lack of accurate volumes and truck percentages should be carefully considered in using these numbers for individual incidents. As reported in a study by the Georgia DOT (GDOT),[7] severe heavy vehicle incidents are often unique and their associated motorist delays fall along a wide spectrum. Further, as noted in a study from the Washington State DOT,[13] Hallenbeck et al. found that motorist delays depend not only on incident durations and lane closures but also on the actual traffic demand exceeding the available capacity. Therefore, average traffic volume profiles may not be suitable for analyzing large-scale incidents where formal detours are established. All these data and methodological concerns with direct VHD calculation rendered the measure unusable. These details are elaborated upon in Appendix C for completeness and for future research reference.

The last three metrics were also deemed out of the scope of this study because of data and methodological limitations. Secondary incidents are often not recorded/documented in the field. Several methods exist in the literature to estimate them based on time and space proximity to primary incidents; however, there is no consensus with regard to those methods. Estimating the queue dissipation time and regain time currently depends on probe-vehicle-based traffic speed data, are limited by the TMC definitions, and involve time-consuming, manual methods.

Datasets

To calculate the RCT and TRT performance metrics, the following datasets and data elements are necessary:

- list of incidents in the after period where TRIP was deployed, list of TRIP-like incidents in the after period, and list of TRIP-like incidents in the before period ("TRIP-like" incidents were identified using several data filtering criteria such as location, vehicle type, crash severity etc., that are explained in more detail later)

- incident timestamps including T_1, T_4, T_5, and T_7

- incident characteristics such as roadway, direction, mile marker, latitude, longitude, day of week, time of day, incident type, severity, lane closure details, vehicle type, cargo spill indicator, HAZMAT indicator, fatality indicator, and injury indicator.

Most of these datasets and data elements could be queried directly from three main data sources: TRIP synopsis reports, Virginia Traffic (VaTraffic), and VDOT's Roadway Network System (RNS) database,[6] described here. Others were derived manually from text entries within each incident record from these same three data sources.

TRIP Synopsis Reports

A TRIP synopsis report (shown in Appendix D) is filled out by the on-scene supervisor (typically the Virginia State Police [VSP] or VDOT) for each TRIP incident, documenting the critical incident timestamps that are reported to VDOT's traffic operations center (TOC). Specific timestamps include the time (1) TRIP is activated, (2) the tow company is notified, (3) the tow company arrives, (4) the NTP is given, and (5) lanes are cleared. In addition, if the situation dictates any stoppage of work by the incident commander because of special circumstances, the begin and end timestamps of those stoppages are also recorded. The form also has fields for accident description, special problems, and solutions. Photographs that show all responding TRIP equipment and personnel must accompany each TRIP synopsis report. The reports are used as the basis of declaring each incident a "successful" or "unsuccessful" TRIP event where the tower either meets or does not meet response and clearance time thresholds for the bonus, respectively.

The VDOT TOC compiled these synopsis reports to provide a full list of after period incidents with TRIP activations, the corresponding VaTraffic incident ID, date of occurrence, roadway, direction, mile marker, responding tower, notes indicating whether the TRIP was

successfully cleared or not (and the reason for not being successfully cleared along with any cancelled TRIP activation), and the TRIP bonus paid. Another list of TRIP-activated incidents was provided by the TOC, containing all timestamps of interest for this study. The individual synopsis reports were used to clarify any inconsistencies in these compiled lists.

VaTraffic

VaTraffic is a web-based VDOT data management and reporting system into which all known abnormal road and traffic conditions are entered, which feeds VDOT's 511 system. Road closures, whether work zones, incidents, or emergency closures because of weather, are reported in VaTraffic by the TOCs, district staff, and contractors. For incidents, the VaTraffic database contains detailed event information such as type, severity, location, and lane closures. The database also contains timestamps for incident start, verification, clearance, and closure (i.e., road fully opened) and lane openings and closures and may contain a text log of approximate traffic queue lengths and responder arrival/departure times. For the TRIP events, the incident ID number shown in Appendix E was used to obtain specific VaTraffic incident logs.

Roadway Network System

VaTraffic logs are created through real-time data entry; therefore, miscoding can occur in some instances. For example, vehicle classifications may not be correct or data entry may involve misspellings. Therefore, the RNS was utilized as a cross-reference to ensure all TRIP vehicle criteria type crashes (tractor trailers, large motor homes, buses, and vehicles with a gross vehicle weight rating of 26,000 lb or more) were properly identified and processed for the before and after periods within the space boundaries of the TRIP pilot. The RNS database contains crash data extracted directly from Virginia's Traffic Records Electronic Data System and enhanced with VDOT linear reference system details including road name, route number, direction, mile marker, latitude, and longitude. Virginia's Traffic Records Electronic Data System is an automated data system maintained and operated by the Virginia Department of Motor Vehicles Highway Safety Office that centralizes all of Virginia's roadway crash data from the police records. These police records contain crash details necessary for investigation and legal recourse, which include incident location, date and time (T_0 in Figure 2), weather conditions, vehicles involved, and the driver actions just before the crash occurred; however, traffic-related information such as incident clearance time, lane closure status, responder arrival times, and queue length are almost never recorded. To obtain these additional details of interest, each RNS crash record of interest needs to be cross-referenced to its corresponding VaTraffic incident record using the following common data elements: date and time, road number, direction, mile marker, latitude, longitude, and crash description notes.

Task 2: Collect and Filter Data

TRIP synopsis reports captured date, location, and timestamps of TRIP-activated crashes in the after period. These were cross-referenced with detailed VaTraffic incident reports to obtain additional information such as incident detection/verification, lane closures, roadway clearance, and incident duration. The next step was to extract TRIP-eligible incidents from

VaTraffic and RNS in the before and after periods. Figure 3 shows the various filters developed to ensure the selected before period incidents were comparable to the after period incidents. These filters were developed based on available data and were vetted by the project technical review panel. The types of before period crashes extracted included all incidents that met the TRIP activation criteria shown in Appendix A.

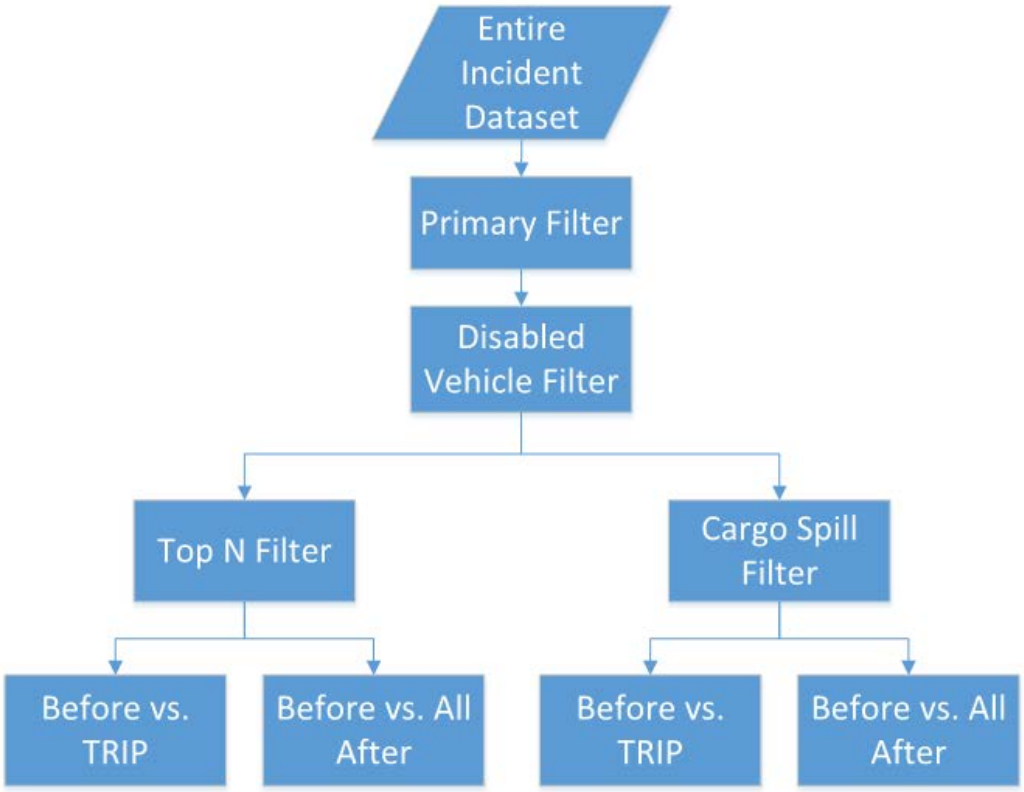

Figure 3. TRIP Analysis Data Filters. TRIP = towing and recovery incentive program.

Primary Filter

A primary filter was created following a detailed process shown in the flow chart in Figure 4. There were five main filtering criteria:

1. temporal range of December 15, 2014, to December 14, 2018

2. spatial boundaries comprising the interstate route segments shown in Table 1

3. incident types of VaTraffic tractor trailer accident, VaTraffic disabled tractor trailer, or VaTraffic vehicle accident / multivehicle accident / numerous vehicle accident where space/time matched an incident in RNS with one or more commercial vehicles

4. heavy vehicle towing operations performed

5. incident intensity of RCT $\geq$ 30 minutes and lane-blocking crash [RCT was used as a data filtering criterion to exclude low duration incidents for which TRIP would not

have been activated; therefore, this filter criterion was not expected to confound the analysis results where RCT is also selected as a program performance measure; a crash was defined in this study to be lane-blocking if any travel lane was recorded as blocked in VaTraffic at any time during the incident timeline, including recovery.].

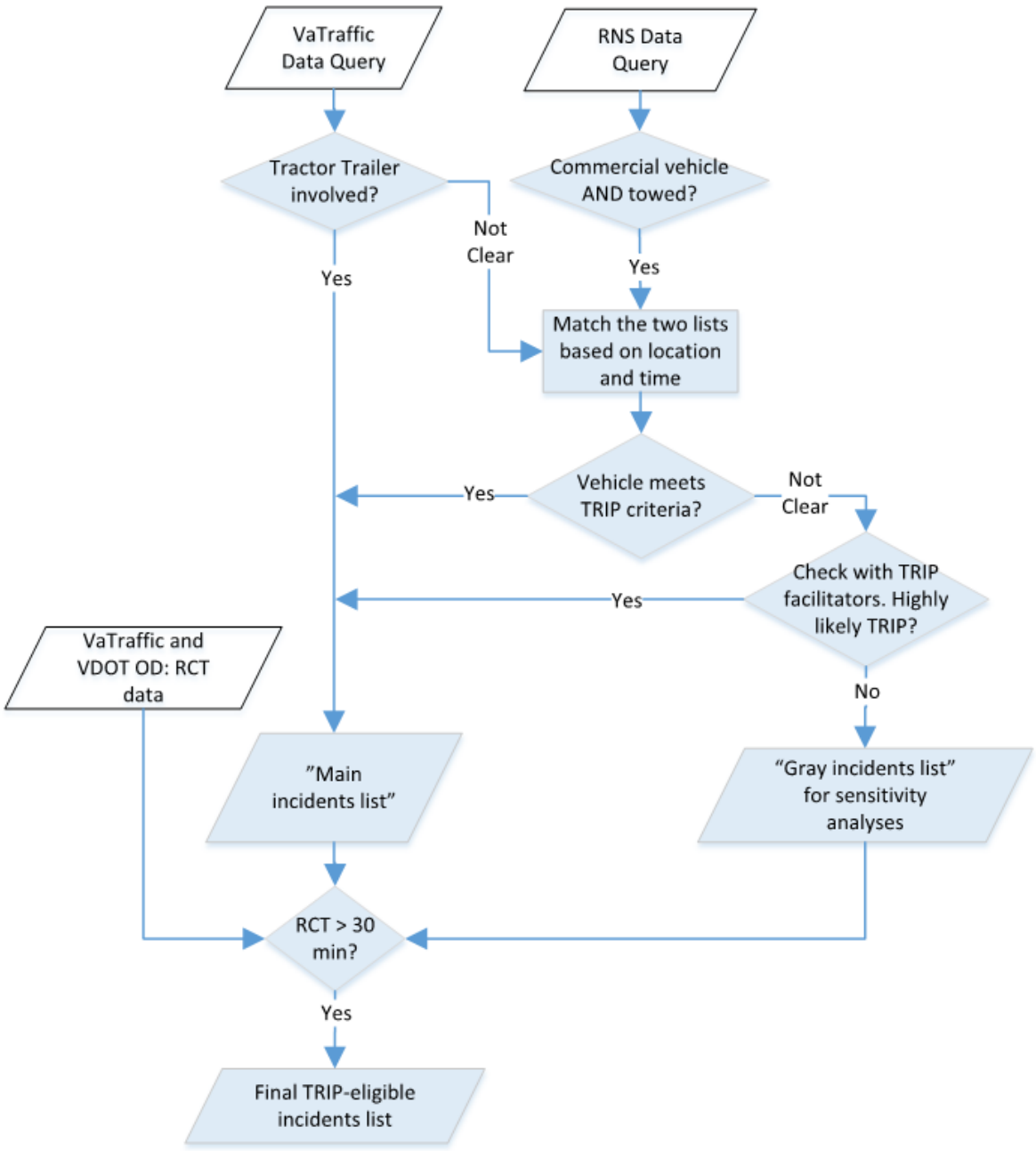

Figure 4. Details of Primary Data Filter. RNS = roadway network system; TRIP = towing and recovery incentive program; VDOT OD = Virginia Department of Transportation Operations Division; RCT = roadway clearance time.

To assist with identifying crashes involving miscoded incident types in VaTraffic (e.g., a box truck coded as a passenger vehicle), the RNS database was queried using the first four criteria in the list (RCT and lane closure are not available in RNS but are available in VaTraffic). Basic incident data elements such as incident ID, description, road, direction, mile marker, latitude, longitude, date, and time were captured from RNS. For each RNS incident record, one incident record in VaTraffic was identified that matched all of these common data elements.

Matching the results of the VaTraffic and RNS queries involved two manual steps. First, spatial boundaries could not be coded directly in the VaTraffic and RNS queries using one consistent spatial reference system such as roadway-direction and mile markers or latitude-longitude pairs. Although mile markers for ramp incidents in VaTraffic are often coded with reference to the gore and not the mainline, the TRIP pilot boundaries were defined in terms of mainline mile markers. Therefore, the databases were queried to include all crashes within the known mile markers on each interstate as well as the approximate extents of the latitude-longitude pairs derived from these known mile markers. Crash records from the two databases were deemed initially matched if both contained the same route number and direction, the mile markers of the two records were within 5 miles of each other, the start times of the two records were within 1 hour of each other, and the descriptions were similar.

Second, incidents involving vehicles that clearly met TRIP activation criteria (Appendix A) were included in the main list of incidents for analyses. RNS database crashes coded as involving commercial vehicles also included TRIP-ineligible vehicles such as cargo vans and pickup trucks. Such incidents involving vehicles that clearly did not meet TRIP vehicle criteria were identified using the vehicle make and model details and were removed to reduce data skew. For some incidents, the RNS vehicle make and model did not clarify their TRIP-eligible status (e.g., a vehicle make and model that could be either a large freight vehicle or a small cargo van); thus, these incidents were noted and brought to the attention of TRIP facilitators who have extensive field experience coordinating heavy vehicle crashes. Based on the information initially available to the first responders for each incident, such as vehicle details, location, date, and time, the TRIP facilitators used their experience and expertise to discuss and explain whether they would or would not activate TRIP in each case. For each incident where such a decision was clear, it was accordingly included or excluded from the analyses. All incidents where the facilitators together could not make clear decisions were identified as “gray” incidents and used for sensitivity analyses described in detail later.

Additional factors beyond the criteria in Appendix A considered by the TRIP facilitators for TRIP activation included the following:

- *Vehicle type, size, and ownership*. For example, a county or municipality may request its own towing equipment for a crash involving its fire truck.

- *Shoulder width*. The facilitators were more inclined to activate TRIP at locations with narrow or limited shoulders.

- *Time of day*. The facilitators were more inclined to activate TRIP if peak period traffic was deemed to be in effect or imminent.

- *Day of year* (vacation/holiday traffic). Facilitators considered high-traffic situations for more readily activating TRIP.

- *Time to remove vehicle*. If the vehicle required a simple hook and pull, TRIP was less likely to be considered.

- *Locations with higher traffic*. Such locations prompted the facilitators to activate TRIP more readily.

- *Severity*. The facilitators considered the incident severity as witnessed by the first responders, i.e., the eyes and boots on the ground. Severity details that surfaced during this study included minor vs. major guardrail impact, fatality, minor vs. major jack-knife, and empty vs. full load.

The TRIP facilitators clearly noted that the TRIP activation criteria could not be fully codified and allowed for leeway for the first responders to make that decision based on their own experience and judgment. For the same reason, the data filtering process cannot be fully automated and requires human interpretation of the crash data. It should also be noted that RCT is not directly available from the VaTraffic database. VDOT's Operations Division used lane closure details to calculate RCT for each incident and queried it via Tableau. They also queried HAZMAT indication, cargo spill indication, and severity indication (fatal, injury, or none) for each incident. These Tableau queries used the same temporal range and spatial boundaries as the VaTraffic Oracle database query. Referencing RCT and lane-blocking information from VaTraffic, the fifth primary filter criterion was applied to all incidents from the earlier steps, resulting in a consolidated list of TRIP-eligible incidents in the before and after periods.

Disabled Vehicle Filter

This filter was developed in an evolutionary manner after the initial analyses to account for some significant data skew observed in the results after the primary filter was applied. In essence this filter removes "disabled vehicles" from the analysis.

Top N Filter

Given that severe, heavy vehicle incidents in a region are relatively few in number and each of them has distinguishing characteristics, additional data filters and analytics were developed to increase confidence in the final results. First, to analyze all TRIP-activated incidents (N in number), they can be compared to the top N similar before period incidents. The rationale employed is that TRIP is implemented to address such severe incidents. This filter is termed "Before vs. TRIP Top N Filter" in Figure 3. Although such a comparison is ideally appropriate and desirable, especially during the early days of the program, inadvertently TRIP may not have been activated for some severe crashes and may have been activated for some less severe crashes, thereby resulting in an overestimation of the TRIP benefits.

To overcome this potential bias, a "Before vs. All After Top N Filter" was developed. Instead of using a static number N, this filter derives the number of incidents to be compared

between the before and after periods using the incident log data. The hypothesis behind this filter is that any benefits observed for the severe heavy vehicle crashes in terms of a selected measure resulted from the TRIP implementation.

Figure 5 presents this approach in a graphical manner using total RCT savings on the Y-axis and number of top N incidents on the X-axis. All the filtered before and after period crashes can be arranged side by side in two columns on a spreadsheet and independently ordered by the decreasing value of their RCT values, as shown in the example in Table 2. For each row of such an ordered pair of incidents, the RCT savings is calculated by subtracting the after period RCT from the corresponding before period RCT and populated in a third column. A fourth column can then be created to calculate the cumulative RCT savings for all the top N incidents in this list. For example, the total cumulative RCT savings for the second row will be the sum of the RCT savings from both the first and second rows.

As more incidents are analyzed in this way, there comes a point at which the total RCT savings will attain a maximum value (corresponding to the values δ on the Y-axis and N1 on the X-axis in Figure 5). RCT savings then start decreasing because the non-TRIP crashes in the after period are likely to be more comparable to the non-TRIP crashes in the before period. If, for example, of these N1 crashes, N2 is the number of crashes for which TRIP was activated, then the average RCT savings per TRIP activation would be calculated as δ/N2. Multiplying this average RCT savings with the total number of TRIP-activated crashes in the program (N) provides the total RCT savings from the TRIP implementation.

The Before vs. All After analysis filter is also expected to capture potential improvements in the overall culture of incident management, including improved training, equipment, and focus on quick clearance with non-TRIP crashes. However, for every non-TRIP incident included in the top N1 after period incidents, there is a possibility that the true TRIP benefits are being diluted by non-TRIP crash activity that is governed by the tow rotation list and responded to by a tower that does not have the proper equipment or training.

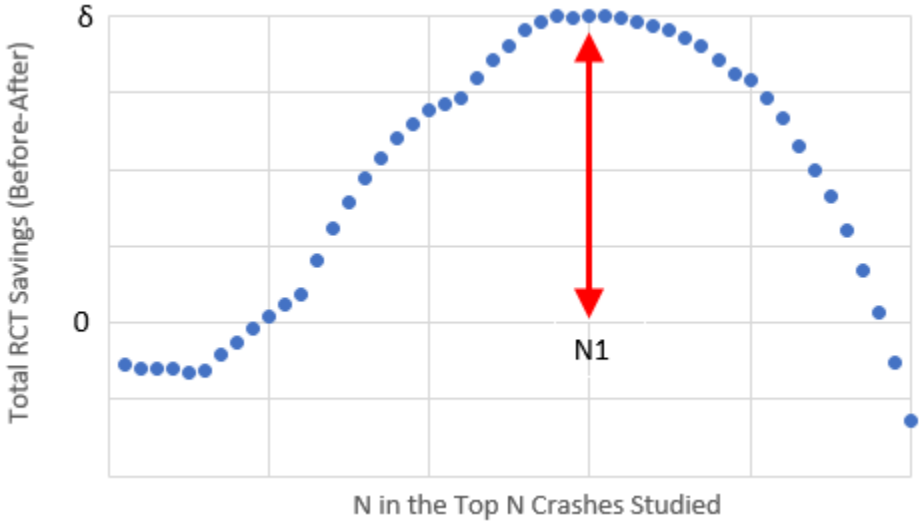

Figure 5. Theoretical Expectation of Before vs. All After Period Top N Crashes. RCT = roadway clearance time.

Table 2. Example Analysis of Before vs. All After Period Top N Crashes

RCT Rank	Avg. Before RCT	Avg. After RCT	RCT Savings	Total RCT Savings
1	850	900	-50	-50
2	840	860	-20	-70
3	820	820	0	-70
4	810	700	110	40
5	800	650	150	190

RCT = roadway clearance time.

Cargo Spill Filter

The final analysis filter examined only crashes involving a cargo spill, which is a special area of emphasis for TRIP operations given that required response protocols (personnel and equipment) are designed to clear such incidents quickly. If sufficient sample sizes of incidents are available in both the before and after periods, then cargo spill crashes can be separately analyzed. All the cargo spill crashes in the before period can be compared to cargo spill crashes where TRIP was activated (applying the Before vs. TRIP filter) or to all the after period cargo spill crashes (applying the Before vs. All After filter). These two comparisons provide a lower and an upper bound of benefits observed. It should be noted that cargo spills are likely to include some fatal and HAZMAT crashes, both of which are outside the scope of the TRIP towing and recovery responders, and both aspects will considerably increase the RCTs. Therefore, either the fatal and HAZMAT crashes should be removed when sufficient samples are available or suitable caveats should be included along with the analysis results.

Task 3: Compute and Analyze Performance Metrics

Calculating Metrics

Performance measures related to the incident timeline (Figure 2) can be computed directly from recorded timestamps of an incident. Some measures can be estimated if their pertinent timestamps are not available for an incident.

Motorist delays can be computed by several approaches including simulations, queue-delay models, and empirical speed data analysis. Probe-vehicle-based traffic speed data such as the National Performance Management Research Data Set (NPMRDS) are already available to agencies, making the empirical method increasingly affordable and accurate. Queue lengths can also be calculated from probe-vehicle-based traffic speed data if segment lengths and sample sizes are reasonable. Secondary incidents are directly captured in the police crash records in some jurisdictions. Otherwise, they can be estimated using available crash records and the traffic data associated with that time and space.

For calculating a B/C ratio, program benefits can be estimated by monetizing improvements in RCTs, vehicular traffic delays, and/or secondary crashes. Approximate dollar rates for each of these measures can be derived from the literature. One example is the $345 per minute of incident duration mentioned in the Washington State DOT report by Hallenbeck et al.[13] The consumer price index (CPI) inflation calculator from the Bureau of Labor Statistics[14]

can be used to convert the average rate from the literature to the year of interest. Program costs can be obtained from the agency invoices and financial systems.

For the Richmond pilot, the lane clearance timestamp for some non-TRIP incidents was missing. In these cases, incident end time was used to estimate RCT. For crashes on ramps, long duration incidents, and incidents where tow response was paused for safety reasons, RCTs were computed manually.

Since VaTraffic does not currently have a provision to record the arrival of the first tower/wrecker on the scene (T_4) in a date-time field, it is documented for only some incidents at the TOC operator's discretion in the text notes field. Therefore, TRT calculation was inherently a manual process. After identifying all of the incidents that contained "tow" or "wreck" in the text notes field, the researchers manually parsed the text field to identify any mention of the tower arrival time. For incidents missing the tower arrival time in the notes, an appropriate surrogate timestamp was not available; therefore, TRTs were not calculated for those incidents.

As described earlier, this study identified several data and methodological concerns with direct VHD calculation; therefore, benefits were estimated by monetizing RCT. Using incident duration and delay details documented in the GDOT TRIP evaluation report,[7] the average dollar value per hour of incident duration was calculated as $64,220.20 (in 2011 dollars). The equivalent average rate in January 2019 dollars was estimated as $73,402.85. It should be noted that this average dollar value is a function of actual traffic demand, truck percentage, roadway capacity, number of lanes blocked, severity of the incidents, the cargo involved, etc.; however, these details on TRIP interstates in Georgia in the years 2007-2009 were not available in the GDOT report. The average truck percentages noted in the report (around 10 percent) were indeed similar to the average truck percentages along the Richmond interstates in the 2014-2018 period. In the absence of these details and any other rate for high impact, heavy vehicle crashes in the reviewed literature, the researchers assumed that the average dollar value from the GDOT report was applicable to the Richmond site. Program costs were obtained from the VDOT TRIP manager.

Exploring Metric Statistics

Counts of filtered crashes by time period (before, after, etc.), day of week, time of day (day or night), location (route), and crash type (fatality, cargo spill, HAZMAT, etc.) are simple yet essential statistics to understand any skew in the overall dataset. For each evaluation metric and time period (by year or by before-after period), the primary statistics of interest for analysis are the average, median, and standard deviation within each time period. The average and the median statistics provide an understanding of the general trends and skew of the data. Standard deviations also help in understanding the variability of the metrics and in testing if average changes in a metric over time are statistically significant.

Developing Visualizations

Visualizations help in exploring and analyzing the metrics, as well as in communicating the methods and results to wider audiences. Effective visualizations for incident management

metrics include cumulative distribution functions (CDFs), bar charts, scatter plots, and spatial maps. CDFs are a recommended method to provide visualization of trends in RCT for the before, after, and TRIP incident lists. The CDF curve presents the percentage of incidents (on the Y-axis) that had RCTs below the point on the curve (with RCT on the X-axis). The Y-axis provides some normalization by removing the actual number of incidents in each period. CDFs help in understanding the distribution of the performance measures and their normalized frequency. Even if the averages over two periods were close, specific ranges of performance measures can improve from one period to another. In general, the best benefits are evidenced by the "S" curve moving to the left (i.e., TRT, RCT, etc., is decreasing) and becoming more vertical (i.e., data are less variable). If the CDF "S" curves from two periods are overlapping, the benefits are likely not significant.

Scatter plots of individual incident metrics, along with the 95th percentile confidence intervals, reveal the dispersion and the statistical significance of the differences in the metrics between different incident lists. Stacked bar charts of major components of the incident timeline have been effectively employed in the literature to provide a visualization of the impact of TRIP. Geographic maps of incidents using latitude/longitude show the spatial distribution of the incidents along each corridor and time period and the magnitudes of their performance metrics.

All of the metrics in this study were computed using Python, Microsoft Excel, and Visual Basic Application (VBA). Visualizations were developed in Tableau, as it provides user interactivity and drill down capabilities.

Performing Sensitivity Analyses

The AASHTO Red Book[15] defines sensitivity analysis and its purpose clearly and succinctly as follows:

> Sensitivity analysis is an important adjunct to benefit-cost analysis when the analysis yields a single expected value for the present value of benefits and the present value of project costs. In such instances, the benefit-cost analysis appears more precise than it actually is in practice. Sensitivity analysis is a way to formally recognize the uncertainty of key factors, and to experiment with alternative values in an organized fashion. Operationally, sensitivity analysis involves re-calculating project benefits and/or costs under different scenarios or combinations of the key factors.
>
> To reduce the cumbersomeness of the sensitivity analysis, the analyst needs to focus on the factors that are (a) key to the analysis, (b) not known with a high level of certainty, and (c) not already modeled directly using Monte Carlo procedures. In addition, the analyst should not construct logically-inconsistent combinations of variables on which to perform sensitivity analysis.

From a TRIP evaluation perspective, key factors that are uncertain include (1) the number of years for which TRIP is implemented; (2) the frequency, severity, locations, time of day, and day of week for heavy vehicle incidents from one year to another; (3) how comparable the before and after period incidents identified to be TRIP-like or TRIP-eligible with the actual TRIP-activated incidents are; and (4) the level of efficiency of on-scene incident management including communications among responders and changes to agency policies over time.

Depending on the direction and magnitude of changes in any of these factors, the observed TRIP benefits can increase or decrease.

To account for the first factor, an analysis was conducted on four different horizon years of deploying the Richmond TRIP: 1, 2, 5, and 10. The longer the program is deployed, the less influential capital expenses and startup costs are.

To account for the other three factors, two analyses were carried out. First, the TRIP benefits were calculated by both excluding and including the gray incidents identified by the TRIP facilitators, as explained in Figure 4. Second, some of the top RCT incidents in different periods were removed in calculating the program benefits. The top 1, 2, or 3 incidents in each period (before or after) or each year in the before period were removed, and the TRIP benefits were calculated in each of those scenarios.

Although growth of traffic is also an important unknown factor in the analysis, so are the geometric and operational improvements implemented to mitigate the impacts of traffic growth. This study assumed that these two factors are complementary over time and space, therefore canceling out the effects of each other.

Task 4: Qualitative Assessment

A qualitative assessment of the TRIP pilot was performed by conducting telephone interviews with VDOT and Parsons TRIP managers, VSP personnel, and towing vendors that participated in TRIP. The questions asked varied based on roles within the program.

VDOT/Parsons TRIP Managers

VDOT and Parsons TRIP managers were interviewed together via a conference call with the research team. The following topics were discussed:

- identification of stakeholders
- initial outreach
- vendor application process
- zone development
- stakeholder meetings
- equipment and training needs
- feedback on program.

Virginia State Police

VSP personnel that were involved in TRIP operations were interviewed individually via a telephone call from the research team. The VSP interviewees included a first sergeant, a lieutenant, and a dispatcher. Topic areas covered included program startup, notification, on-scene activities, after-action reviews, incident management culture, general impressions, and areas of improvement. Specific questions posed to the VSP personnel included the following:

- Were there any initial concerns going into the TRIP program and how were they resolved?

- How would you compare and contrast VSP dispatcher actions for similar crashes before and with TRIP?

- How would you compare the TRIP notification process with the towers compared to similar heavy vehicle crashes in the past?

- Were there any issues with on-scene communication with VDOT or towing vendors?

- What is your opinion of the monthly meetings and after-action reviews?

- Is there a noticeable change in culture with towing response and recovery?

- What are your general overall impressions with TRIP?

- Are there areas where the program could be improved?

Towing Vendors

Of the 11 towing vendors that participated in the TRIP pilot, 8 were interviewed. Numerous attempts were made to schedule interviews with the remaining 3, but those attempts were unsuccessful. The structure of the interviews was based on three categories: (1) program development, (2) operations, and (3) post-operations. In addition, vendors were asked about their overall impressions of the program.

Program Development

Program development questions were framed to gauge opinions on the process employed by VDOT and Parsons leading up to the TRIP pilot start date of December 15, 2017. This process included initial meetings, equipment inventory, inspections, and training. In addition, each towing vendor was asked about general impressions going into the program and thoughts on ways to improve program development processes.

TRIP Operations

Interview questions about operations focused on aspects of the incident timeline shown in Figure 2. Specifically, vendors were asked to elaborate on the following:

- *Notification*
  - How were you notified?
  - What kind of details did you hear about the crash?
  - What is your process after notification?
  - Were there any issues with equipment availability?
  - Are there areas that can be improved with the notification process?

- *Response*
  - What were the response units/vehicles?
  - Were there ever any issues getting all units activated to respond?
  - Were there ever any challenges arriving at the incident scene?

- *Arrival on-scene*
  - Were there ever issues with staging your equipment?
  - Who did you first communicate with upon arrival?
  - Did you have issues identifying or finding the Incident Commander?

- *Notice-to-Proceed (NTP)*
  - Who provided the NTP?
  - Did you keep track of the timestamp of the NTP?
  - Any general issues encountered with the NTP?

- *Recovery and clearance*
  - Were there lessons learned from unsuccessful TRIP operations?
  - Did your clearance times improve through the pilot period?
  - Any general issues with recovery and clearance and how can it be improved?

Post-Operations

Two post-operational subcategories were explored with the vendors including after-action reviews and invoicing:

1. *After-action reviews*
   - Did you attend all the meetings?
   - What are your opinions of these meetings?
   - Did you learn from others' experiences?

2. *Invoicing*
   - Was the process clear and payment timely?

General Impressions

The following questions were posed to towing vendors in order to gauge their overall impressions of TRIP:

- Do you feel the TRIP program has changed the overall towing and recovery culture to other crashes?

- What are your overall thoughts of the TRIP program?

- Are you interested in continuing your participation in the TRIP program?

RESULTS AND DISCUSSION

Based on the analytical methods described in the "Methods" section, the following results are presented in terms of performance metrics (RCT and TRT) in relation to the data filtering process.

Primary Filter

The primary filter resulted in 776 unique incidents, of which 505 were from the before period (2015-2017) and 271 were from the after period (of which 64 were TRIP incidents). Table E1 of Appendix E shows all TRIP-activated incidents during the pilot including date, location, towing vendor, incident ID number, notes on successful/unsuccessful events, and incentive bonus payout per event. Of importance to note, Table E1 shows 72 TRIP activations; however, 4 were canceled and 4 were located on ramps. Because of limited data on ramp-involved incidents in VaTraffic, which prevented the ability to compare before and after data, these crashes were removed from the analysis. Table 3 shows the number of incidents in the before and after periods aggregated by interstate. The number of incidents on I-95 was consistently higher throughout the before period, after period, and TRIP incidents than on all other interstates. The number of heavy vehicle crashes increased considerably in 2018 compared to previous years. This observation was qualitatively corroborated by first responders in the area.

Table 4 shows the VaTraffic event type descriptions for all primary filter incidents. As expected, the majority of incidents were labeled "Tractor Trailer Accident." In addition, disabled tractor trailer is one of the VaTraffic incident event types resulting from primary filter application (e.g., disabled tractor trailers were coded to be included in the filter). The reason disabled tractor trailer incidents were included in the filter is because three TRIP activations in 2018 were tractor trailer disablements.

Of these 776 incidents, 60 were identified from the RNS database. Of these 60 incidents, 50 were clearly TRIP-eligible based on the established TRIP criteria, 8 were identified by the TRIP facilitators as highly likely to be TRIP-eligible, and the other 2 were identified as "gray" incidents for which TRIP may or may not have been activated by on-scene first responders depending on other factors.

Table 3. Incident Frequency Statistics by Roadway and Year After Primary Filter Applied

	Roadway					
Period	**I-95**	**I-295**	**I-64**	**I-85**	**I-195**	**Total**
2015	79	27	31	15	0	152
2016	85	27	28	17	0	157
2017	113	37	21	22	3	196
2018 (TRIP)	24	15	13	11	1	64
2018 (non-TRIP)	124	35	29	17	2	207
Total	425	141	122	82	6	776

TRIP = towing and recovery incentive program.

Table 4. Incident Frequency Statistics by Incident Type and Year After Primary Filter Applied

Period	VaTraffic Event Type					
	Disabled Tractor Trailer	Tractor Trailer Accident	Multi-Vehicle[a] Accident	Vehicle[a] Accident	Vehicle[a] Fire	Total
2015	0	129	5	18	0	152
2016	8	138	1	10	0	157
2017	39	142	4	11	0	196
2018 (TRIP)	3	51	0	8	2	64
2018 (non-TRIP)	66	132	1	8	0	207
Total	116	592	11	55	2	776

TRIP = towing and recovery incentive program.
[a] The term "vehicle" was used in VaTraffic but refers to buses, motorhomes, and box trucks based on Roadway Network System descriptors.

Disabled Vehicle Filter

After the primary filter data were examined, anomalies in disablement event types were found in the before period; i.e., no disablements are shown for 2015 and only 8 are shown for 2016. This anomaly presented concerns with regard to confidence with respect to VaTraffic coding of disablements in the before period. Upon review of the RCT times of disabled tractor trailer disablements, most were cleared within 120 minutes, as shown in Figure 6. In addition, in 2018, there were 66 disablements in the after period for non-TRIP incidents. Therefore, to prevent skew of the overall dataset, disablements were removed using the disabled vehicle filter. The resulting dataset of incidents by interstate in the before and after periods is shown in Table 5.

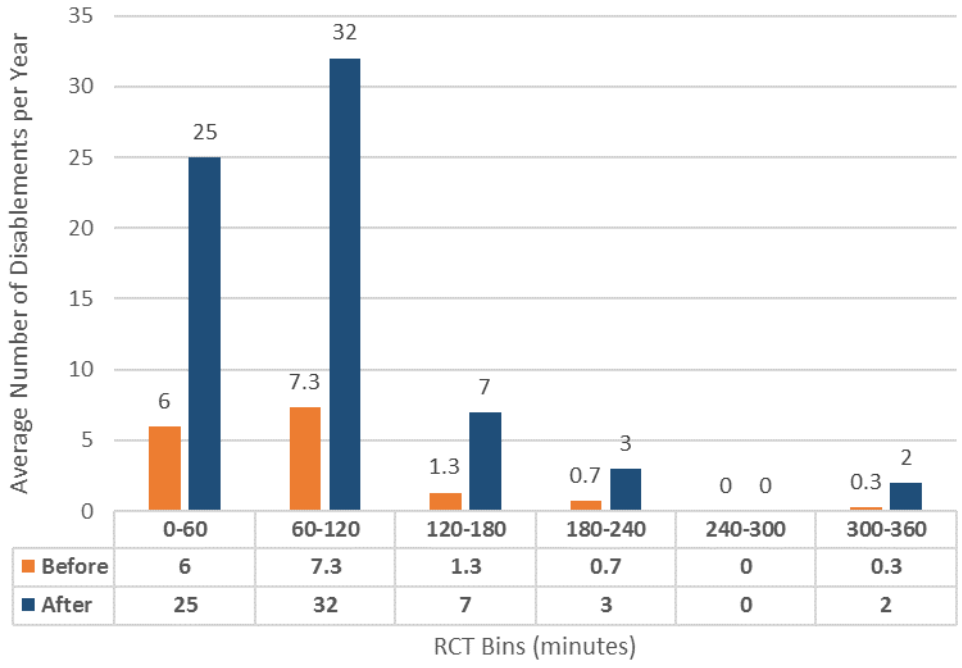

Figure 6. Frequency of Disabled Vehicle Incidents by Period and Duration. RCT = roadway clearance time.

Table 5. Crash Frequency Statistics by Year and Roadway After Disabled Vehicle Filter Applied

Period	Roadway					
	I-95	I-295	I-64	I-85	I-195	Total
2015	79	27	31	15	0	152
2016	81	26	26	16	0	149
2017	84	31	20	19	3	157
2018 (TRIP)	23	14	12	11	1	61
2018 (non-TRIP)	82	24	23	11	1	141
Total	349	122	112	72	5	660

TRIP = towing and recovery incentive program.

Table 6 shows the number of incidents, average RCT, and median RCT produced by this filtering process for each evaluation year including TRIP only incidents (note that TRIP incidents were included in the 2018 data). Observations from this table include the following:

- The total number of incidents that met the TRIP criteria increased in the after period (2018) compared to the before period years (2015-2017).

- Average RCT decreased in the after period (137 minutes) compared to two before period years (164 and 161 minutes for 2015 and 2017, respectively). Given the median RCTs for these periods were similar, the TRIP pilot has likely decreased the duration of high severity incidents in the after period. In contrast, the average RCT for 2016 was similar to that of the after period and the median RCT was 10 minutes shorter, pointing to a skewed distribution of incidents toward the lower end of RCTs.

- The average and median RCTs for TRIP only incidents were higher than the average and median RCTs in the before period (2015-2017) and the after period (2018), which comprised all incidents including TRIP incidents. This is an expected outcome given that TRIP focused on high impact incidents.

Figure 7 shows the cumulative density function after application of the primary and disabled filters for RCT in the before period (3 years combined), after period (which included TRIP incidents), and TRIP only incidents. The plots show an increase in RCT for TRIP only incidents as the blue line (TRIP data) is shifted to the right of the red (before data) and orange (after data) lines. At a cumulative distribution of 50 percent (the median value), the before and after RCT values were nearly identical at approximately 88 minutes whereas the mean RCT for TRIP only incidents was 165 minutes.

Table 6. Roadway Clearance Time Statistics by Year and for TRIP Crashes After Disabled Vehicle Filter Applied

Performance Statistic	2015	2016	2017	2018[a]	TRIP
No. of Incidents	152	149	157	202	61
Average Roadway Clearance Time (min)	164	134	161	137	217
Median Roadway Clearance Time (min)	93	86	98	96	166

TRIP = towing and recovery incentive program.

[a] 2018 includes TRIP crashes.

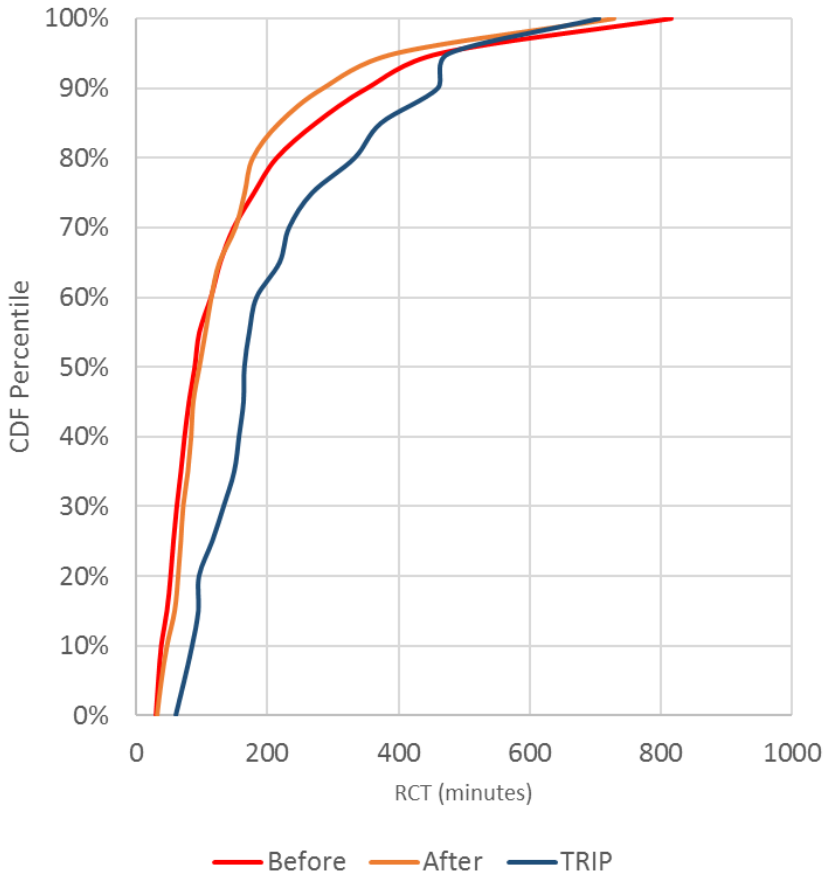

Figure 7. Cumulative Distribution Function (CDF) of Roadway Clearance Times After Disabled Vehicle Filter Applied. TRIP = towing and recovery incentive program.

In all of the CDF graphs, the blue curve represents the TRIP incidents list, the orange curve represents the after period, and the red curve represents the before period. The slope of the curve indicates the level of variability in the data, and the horizontal spread indicates the range in the data. If data points were consistently similar, the lines would be more vertical, and if the pilot project was beneficial, the blue and/or orange curves would be to the left of the red curve.

With regard to the data for TRT, Table 7 shows a low sample ratio percentage in 2015 and 2016 (28.3 and 38.9 percent, respectively) when number of crashes is compared to number of crashes with TRT data. The inclusion of TRT data improved in 2017 and 2018 (65 and 60.3 percent, respectively), suggesting more recent emphasis in capturing these data. TRIP TRT data were documented for all crashes (therefore showing 100 percent). When average TRT was analyzed, all periods showed similar results ranging from 52.7 minutes in 2016 to 61.2 minutes in 2015; however, TRIP showed a higher average TRT than each year with the exception of 2015. It is important to note that unlike the majority of incidents in the before and after periods where the arrival timestamp of a single towing vehicle was used to calculate TRT, TRT data from TRIP incidents were calculated after all required equipment (typically three response vehicles) arrived on-scene (e.g., the last TRT stamp recorded).

Table 7. Towing Response Time Statistics After Disabled Vehicle Filter Applied

Period	No. of Crashes	No. of Crashes With TRT	Average TRT (min)	Median TRT (min)	Minimum TRT (min)	Maximum TRT (min)	Standard Deviation of TRT (min)
2015	152	43	61.9	52	7	210	37.2
2016	149	58	52.7	51	13	104	21.2
2017	157	102	55.9	49	7	177	30.3
2018 (non-TRIP)	141	85	54.4	49	1	170	32.8
2018 (TRIP)	61	61	60.4	55	23	157	23.9

TRT = towing response time; TRIP = towing and recovery incentive program.

With the exception of year 2016, a benefit of TRIP TRT was seen when the standard deviation of the average times was examined. TRIP's average TRT standard deviation was 23.9 minutes, whereas in 2015, 2017, and 2018, the average TRT standard deviations were all above 30 minutes. This indicates more TRT consistency with TRIP. Another benefit of TRIP is seen with maximum TRT data. TRIP's highest TRT was 157 minutes, whereas with the exception of year 2016, the maximum TRT ranged from 170 minutes (in 2018) to 210 minutes (in 2015).

Top N Filter

For a better comparison of TRIP incidents with "TRIP-like" incidents in the before period, additional filters were applied to the data. As described in the "Methods" section, the first filter applied enabled a comparison of the top 61 RCTs in each of the before period years to the RCTs of the 61 TRIP incidents. The second filter applied examined the highest 39 RCTs in each of the before period years and compared them to the highest 39 RCTs of all incidents in the after period.

Before vs. TRIP (Top 61 RCTs)

Table 8 shows the average and median RCTs for the top 61 incidents in the before period (2015-2017), after period (2018; includes 38 TRIP incidents), and TRIP only. The average RCT of TRIP only incidents was lower than in each of the before period years and 2018, as was the case with the median RCT with the exception of 2016. Figure 8 shows a CDF of the average incident RCT from the before years combined, the after period, and TRIP only. The plots show an improvement in RCT for TRIP only incidents as the blue line (TRIP only) is shifted to the left of the orange line (after period) and red line (before period).

Table 8. RCT Statistics for Different Time Periods for Top N (61) Before vs. TRIP Crashes

RCT Statistic	2015	2016	2017	Before Period (2015-2017)	2018[a]	TRIP
Average RCT (min)	306	236	306	283	270	217
Median RCT (min)	270	154	237	220	219	166

RCT = roadway clearance time; TRIP = towing and recovery incentive program.
[a] 2018 includes TRIP crashes.

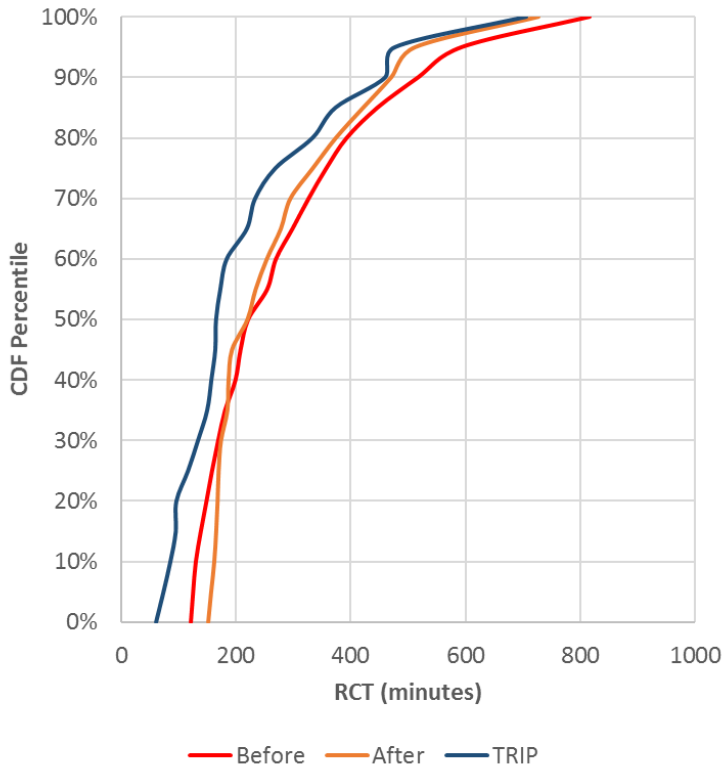

Figure 8. Cumulative Distribution Function (CDF) of Roadway Clearance Times After Top N (61) Before vs. TRIP Filter Applied. TRIP = towing and recovery incentive program; RCT = roadway clearance time.

With regard to the TRT of the top 61 incidents, Figure 9 shows that the average TRT improved for TRIP only incidents compared to the average of the 3 before years by 7.5 minutes (60.4 and 67.9 minutes, respectively). Of the 183 before incidents analyzed, only 94 (or 51 percent) included TRT data; therefore, these results should be considered with caution as there were many incidents in the before period where TRT could not be documented. In addition, as shown in Figure 10, both the RCT and TRT results showed high variability. The dotted lines show the average RCT and TRT values and the gray shaded area indicates the 95th percentile confidence range. For TRT, the confidence range overlaps, providing a low statistical confidence in the difference of their average values. However, for RCT, the 95th percentile ranges do not overlap, thus providing a high confidence in the difference of their average values.

The average, variability (standard error of the mean), 95th percentile confidence interval, and sample size of RCT and TRT for the before period and TRIP incidents after the top 61 filter was applied are presented in Table 9. TRIP average RCT showed a statistically significant improvement at the 95 percent confidence level compared to the before period. The average RCT improvement recorded is 65.8 minutes. TRIP average TRT does not show a statistically significant improvement at the 95 percent confidence level compared to the before period. However, the average TRT decreased by 7.5 minutes, revealing a promising trend. It should also be noted that more equipment and personnel were mobilized for TRIP crashes in comparison to non-TRIP crashes.

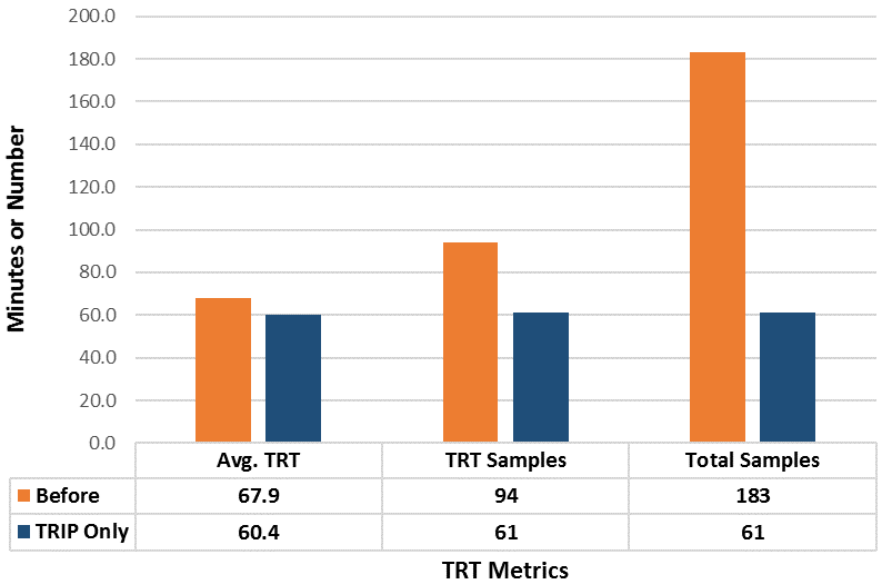

Figure 9. Towing Response Time Statistics After Top N (61) Before vs. TRIP Filter Applied. TRIP = towing and recovery incentive program; TRT = towing response time.

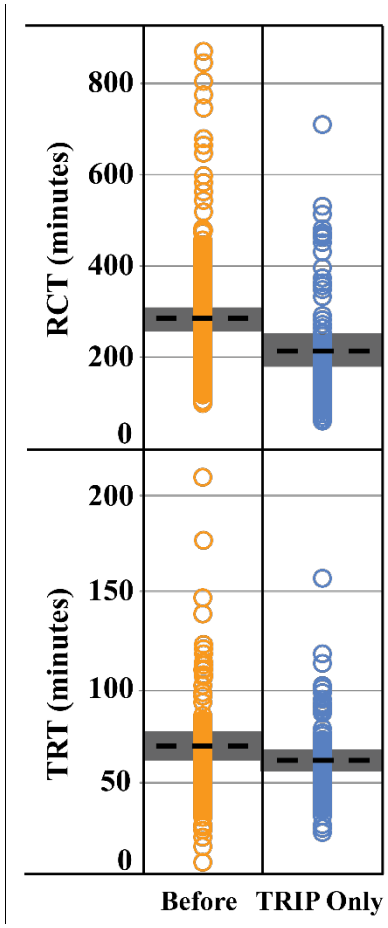

Figure 10. Distributions of Roadway Clearance Times (RCT) and Towing Response Times (TRT) After Top N (61) Before vs. TRIP Filter Applied. TRIP = towing and recovery incentive program.

Table 9. RCT and TRT Statistics for Crashes After Application of Top N (61) Before vs. TRIP Filter

Statistic	RCT (min)		TRT (min)	
	Before	TRIP Only	Before	TRIP Only
Average	282.8	217[a]	67.9	60.4
Standard Error of the Mean	12.5	17.9	3.6	3.1
95% Confidence Interval	258.2-307.3	181.9-252.1	60.8-75.0	54.4-66.4
Sample Size	183	61	94	61

RCT = roadway clearance time; TRT = towing response time; TRIP = towing and recovery incentive program.
[a] Significantly different at the 95 percent confidence level.

Before vs. All After Top N Filter Analysis

Figure 11 shows the results of applying the Before vs. All After Top N filter to the Richmond TRIP crashes. This figure is similar to the theoretical expectations presented in Figure 5 in the "Methods" section. The maximum total RCT savings was 1210.1 minutes when N was 39. Of these top 39 crashes in the after period, 24 had activated TRIP responses. Therefore, the average RCT savings per TRIP activation was 1210.1/24 = 50.4 minutes. The average TRT savings for the same top 39 crashes per year in the before and the after periods was 6 minutes per TRIP activation. Again, it should be noted that this a promising trend, especially when more equipment and personnel were mobilized for TRIP responses.

The top 39 crashes per year in the before and after periods are not comparable for standard deviation; therefore, detailed RCT and TRT statistical significance analysis as presented in Table 9 and dispersion analysis presented in Figure 10 are not applicable to this dataset.

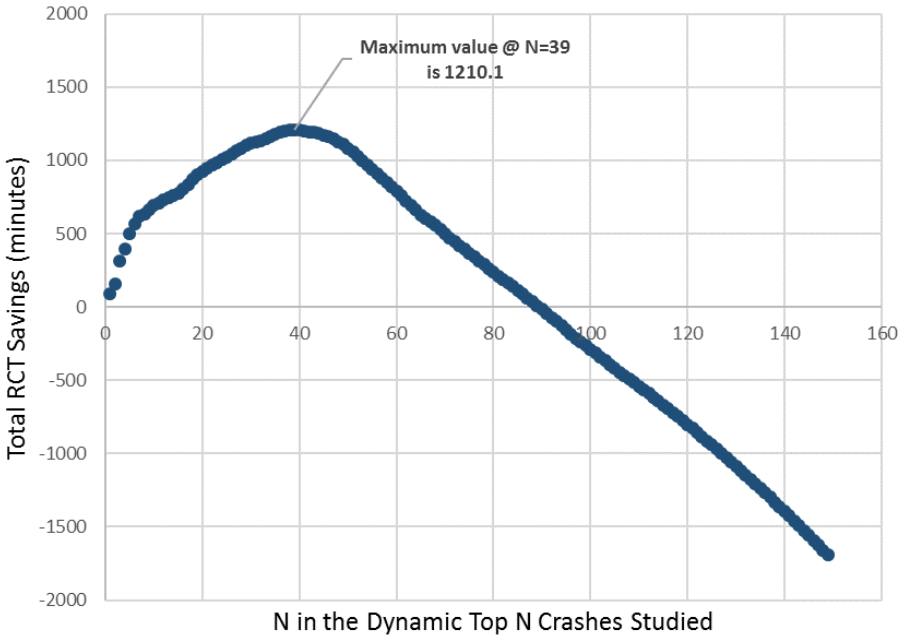

Figure 11. Example Analysis of Before vs. All After Period Top N crashes. RCT = roadway clearance time.

Cargo Spill Filter Analysis

Cargo spill filter analysis results are shown in Table 10, and the dispersion within RCTs in different periods is shown in Figure 12. The results involved 34 crashes in the before period and 21 crashes in the after period, which included 17 TRIP response crashes. The average RCT for TRIP and after period cargo spill incidents vs. the before period improved by 96.1 minutes and 109.6 minutes, respectively. Given the small sample sizes and high variability in incident characteristics and RCTs, these RCT improvements are not statistically significant. Nevertheless, they were practically significant in opening the lanes quicker and in mitigating motorist delays and secondary crashes.

Table 10. Descriptive Statistics of Crashes After Cargo Spill Filter was Applied

Statistic	Before	TRIP	After[a]
No. of Crashes	34	17	21
Avg. RCT (min)	368.1	272.0	258.5

TRIP = towing and recovery incentive program; RCT = roadway clearance time.
[a] After crashes included 17 TRIP response crashes.

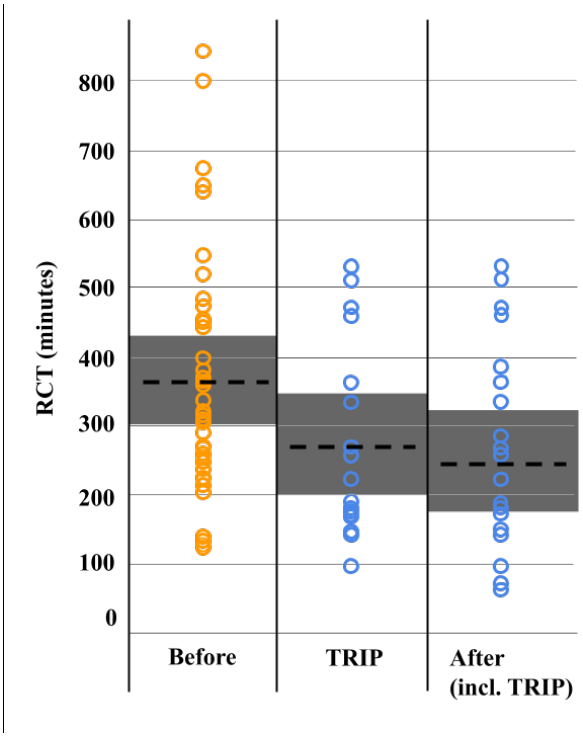

Figure 12. Distribution of Roadway Clearance Times (RCT) of Crashes After Cargo Spill Filter Applied. TRIP = towing and recovery incentive program.

Year-Over-Year Analyses

For future comparison with the GDOT and Florida DOT (FDOT) programs, and for year-over-year comparison for internal evaluation, Figure 13 can be useful. The database available in Virginia currently does not have a TRIP activation timestamp and an NTP timestamp in the before period. When these data are collected, all of the four important TRIP timestamps can be depicted on the one graph shown in Figure 13.

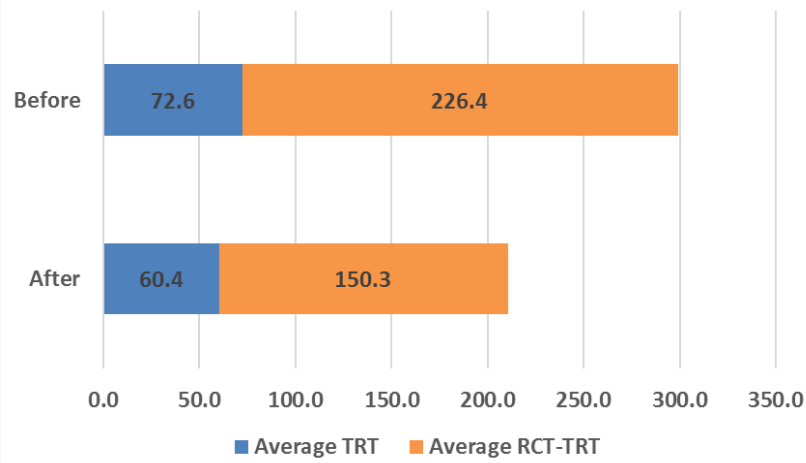

Figure 13. Actual Incident Timelines After Top N (61) Before vs. TRIP Filter Applied. TRIP = towing and recovery incentive program; TRT = towing response time; RCT = roadway clearance time.

Benefit/Cost Ratio

All calculations were performed in constant January 2019 dollars. Program costs for TRIP were $271,434.81 in one-time capital expenses, which included both the development of the program by the consultant ($244,434.81) and the initial tow vendor training ($27,000.00). The operations expense for the first year was $427,250.68, which included the TRIP management costs by the consultants ($292,050.68) and the incentives paid to the tow vendors ($135,200.00). Therefore, the total cost in the first year was $698,685.49.

The first year program benefit by the top N method was calculated as follows:

65.8 minutes of RCT savings per call
x $73,402.85 per hour
x 1 hour/60 minutes
x 68 actual TRIP calls
= $5,473,895.20.

From this method, the B/C ratio for 1 year of the TRIP pilot is 7.8.

The benefit of the Before vs. All After Top N method with 50.4 minutes of RCT savings per call using the same calculation approach is $4,192,767.94. From this method, the B/C ratio for 1 year of TRIP pilot is 6.0. These two benefits values informed the range of benefits observed for the first year (6.0 to 7.8).

It should be noted that the vendor incentive payments will likely increase in the future as more incidents are efficiently managed and cleared within the stipulated 90 minutes from NTP; however, these increased costs would also likely reduce the RCTs and hence improve the benefits. Since there is no known basis for making such adjustments to either the numerator or denominator of the B/C ratio analysis, it was not considered.

Sensitivity Analysis Results

Depending on the number of years the TRIP is continued, the one-time capital expenses will be spread out over time and the B/C ratio will increase. Assuming similar levels of benefits and incentive payouts in future years and using the same calculation approach as explained previously, the low and high B/C ratios were calculated for different horizon years and are shown in Table 11.

The two gray incidents (see Figure 4) across all the years of analyses did not affect the results of the two Top N analysis filters. The impacts of deleting a different number of incidents in different periods on the observed benefits using the Top N Before vs. All After filter are displayed in Table 12. The first row in this table shows the baseline benefits for year 1 deployment, which is the same benefit amount reported earlier. With the program costs remaining the same in all these different scenarios, the total benefits and the percentage changes in the benefits from the baseline are equivalent to the changes in the B/C ratios. From each period or incident list, the top 1, 2, or 3 incidents by RCT value were removed systematically and the 1 year program benefits were calculated for each scenario.

When the top incidents in the before period (either from the entire period or from each year) were removed, the benefits decreased. For example, the reduction in benefits was 17.9 percent and 52.2 percent, respectively, for removing just one incident in the entire before period or from each year in the before period. Similarly, removing the top 1 incident in the TRIP incident list or the non-TRIP incident list in the after period, respectively, increased the benefits by 37.7 percent and 34.4 percent.

Table 11. Ranges of Benefit/Cost (B/C) Ratios for Different Horizon Years

Statistic	Year 1	Year 2	Year 5	Year 10
Annualized Cost[a]	$698,685	$562,968	$481,538	$454,394
B/C Range	6.0-7.8	7.4-9.7	8.7-11.4	9.2-12.0

[a] Constant January 2019 dollars for costs and benefits.

Table 12. Results of Sensitivity Analysis

Period	Year(s) and Incident Type	No. of Top N Incidents Removed	Total Benefits
		0	$ 4,192,767.94
Before	Combined period	1	$ 3,444,059.38
Before	Combined period	2	$ 2,703,669.80
Before	Combined period	3	$ 1,979,918.19
Before	Each year	1	$ 2,004,875.14
Before	Each year	2	$ (16,637.97)
Before	Each year	3	N/C
After	TRIP	1	$ 5,773,374.90
After	TRIP	2	$ 6,946,351.64
After	TRIP	3	$ 8,086,052.45
After	Non-TRIP	1	$ 5,623,633.18
After	Non-TRIP	2	$ 6,164,367.14
After	Non-TRIP	3	$ 6,588,635.33

N/C = not calculable; TRIP = towing and recovery incentive program.

The maximum benefit could not be calculated when three incidents in each year of the before period were removed because only the total benefits decreased and the first incident was a non-TRIP incident, leading to a division by zero for the benefits calculation. These considerable changes in benefits highlight the important role of efficient management in realizing a successful TRIP implementation.

Qualitative Assessment

After completing the TRIP pilot, the research team held telephone interviews with VDOT and Parsons TRIP managers, VSP personnel, and the towing vendors to capture their qualitative experiences. This section summarizes the findings from those interviews.

VDOT and Parsons TRIP Managers

VDOT and Parsons TRIP managers were interviewed to provide information specifically related to program development. This included identifying stakeholders, initial outreach to the towing community, the towing vendor application process, stakeholder meetings, identifying equipment needs, developing towing vendor zones, and training. The following is paraphrased commentary from the TRIP managers on each of the topic areas.

Identifying Stakeholders

- The first step in development of the program was to identify primary stakeholders who were going to own and operate the program. An initial kickoff meeting was held with staff from Parsons, VDOT, and VSP to discuss details of the TRIP program. Towing regions and potential towing vendors were identified as well as the primary and secondary stakeholders. Primary stakeholders included those involved with TRIP activation and secondary stakeholders included those involved at a TRIP incident scene but without direct TRIP duties. Time keeping procedures were also discussed.

Initial Outreach to Towing Community

- Parsons' efforts started in March of 2017. In the first two months, face-to-face meetings were held with heavy-duty towers in the region to explain what the TRIP program was about. Outreach started "Day 1" and occurred all through program development. TRIP managers stated, "There were many growing pains as far as outreach goes. Now we have a greater pool of folks with whom we don't have a TRIP relationship, and may never have, but they are buying into and are training for TRIP."

Towing Vendor Application Process

- TRIP is not a bid effort. It is a strictly voluntary program. "The challenge with bidding is you have to identify terms of service that are difficult to do for TRIP. Historically, TRIP programs are run essentially by an agreement."

- There was an application process. Details of TRIP were developed and published online including equipment and training requirements, an application, and a timeline. As outreach was conducted, word got out to the towing community. TRIP management (VDOT and Parsons) worked with potential towing vendors through the summer of 2017. "We conducted another round of personal meetings to explain what would qualify or not; much more efficient than waiting for the applications to come in. We did a pre-inspection fly in. Towing vendors interested had to meet some qualifications and complete the application process."

- Twenty-two towers were identified as potential applicants. Of those 22, applications were received from 15. Eleven of the 15 qualified for the TRIP program. "We wanted the best of the best for the TRIP program. When you start visiting towers, you see that not all 50-ton rotators or wreckers are the same. There are all these dynamics. We wanted verifiable wrecker specs. We didn't certify for the program if the equipment didn't qualify fully, even if they said so. We are telling a story to the world about the TRIP program. Outreach took a lot of time. We didn't want to waste people's time if they didn't qualify for TRIP."

Zone Development

- At the time of application, none of the towers were assigned a recovery zone. TRIP managers had to know the pool of towing vendors before creating zones. "Once the towing pool was established, the first step was to map all the towers and recovery zones then figure out traffic patterns, concentration of crashes, and an efficient way of getting to each location where a towing company can respond within 45 minutes during the day (including mobilization, etc.). One question brainstormed was - do we give them each a small piece of the interstate or do rotation? Fortunately, all 11 towers were able to get a non-sharing, 24x7, no rotation recovery zone. That's ideal."

Stakeholder Meetings

- "We held TRIP review meetings every month. Towers are required to attend unless they have a major reason and call in to notify of absence."

Equipment

- The majority of towing vendors needed to buy some tools or find them for the support vehicles. "All we did was force the towing companies to get organized. At the time of application, you needed the personnel and they needed to be trained - 3 person team (1 supervisor and 2 operators). If you needed to purchase equipment, we wanted proof that by application time they have started the purchase/manufacturing. We did the best to work with everyone to identify what was reasonable to ask today and what was reasonable in the future. The towers figured out that we were not trying to steamroll them into buying equipment, but working with them."

Training

- With the exception of work zone training, which was not available yet, all towers had to be trained and ready to go by the application date. "When we started the program in Atlanta, Parsons put together TRIP level 1 and 2, and WreckMaster courses, and consolidated into 2 TRIP classes. Quick clearance components were added. Hold harmless is not in effect in most states. What WreckMaster traditionally teaches is damage-free recovery and straight towing. The problem is a lot of time is spent on a crash scene. In Virginia, towers and VDOT are now held harmless which opens up doors to quick clearance policies. That's where TRIP works differently. There is also some other training included in the incident command system, including work zones. That whole package, depending on TRIP operator or supervisor, some needed to attend. Focus is to engage in the incident command."

Lessons Learned

- "Outreach and program development is full time job plus - lot of details - unless you have done this work on the ground, you won't know what to look for. You have to understand the towing world. It's a bit of a dance because TRIP towing operations is not a full-time job."

- "One of the challenges with TRIP is very few towing companies had formal training. In our case, less than 10 towers in Richmond area had training. TRIP level 1 and 2 is provided by WreckMaster, they perform beginner to complex wrecking training. Their products already exist."

- Parsons indicated that accepting errors and mistakes is part of the process of starting a TRIP program. Responders and the TOC could make an incorrect decision from time to time on whether to activate TRIP. Being overly critical of mistakes could cause people to not share information, which would impair the implementation of the program. "That's what keeps everyone calm. Every responder has made some mistake from time to time. If we start demanding people not make mistakes, then they will shy away from sharing details. That is the human element. We are going to take good with the bad."

- "Part of the exercise is to manage expectations - that's a big part of the first 7 months. Some towers understand and some get very upset if they do not get a TRIP call."

- "Timely activation of TRIP is critical. Training reinforced the importance for timely activation."

Feedback on Program

- TRIP is viewed as a needed program. Most of the feedback has been verbal; however, a Virginia State Police Division Commander shared a text message from an Area 1 First Sergeant that stated: "This really makes my day when I see this.

TIMS/TRIP in action. A crash on I-95 at 90 MP involving a TT with only one lane available to traffic. First trooper on scene at 1219 hours, TRIP was declared TT in the median with guard rail damage. All lanes open at 1440 hours. Very impressive, awesome team work by my troopers, VDOT, TRIP crew, Fire, SSP and DPI. I just wanted to share the love, have a good Tuesday evening."

Virginia State Police

Interviews were held individually with a VSP first sergeant, a lieutenant, and a dispatcher. Responses to questions were categorized into the following topics: program start-up, notification, on-scene activities, after-action reviews, culture, general impressions, and areas of improvement. Answers to questions were paraphrased and combined where appropriate into topic areas for the three interviews.

Program Start-up

- Were there any initial concerns going into the TRIP program and how they were resolved?

  "There may have been some skepticism. As an agency, we are slow to change. Any new program, you are skeptical that it would save time in such a big operation like this I was concerned that TRIP was going to put a lot of effort on the troopers. There were a lot of growing pains but I think the only hiccups were on our part - VSP troopers being aware of coordinating with the towing companies and making sure that they are meeting all of the responsibilities. The TRIP program was well put together by VDOT."

Notification

- How would you compare and contrast dispatcher actions for similar crashes before and with TRIP?

  "Right now when a trooper declares TRIP, we notify TOC and they take over. TOC gets back to us within minutes that TRIP is declared. Earlier, we understood that our dispatchers could declare TRIP. Even if they could see on CCTV, they did not feel comfortable calling tower. They wanted on-scene confirmation. But that has changed now."

- How would you compare the TRIP notification process with the towers compared to similar heavy vehicle crashes in the past? Any ways to improve the efficiency?

  "It's more streamlined. We have protocols in place on what to do. We have specific wreckers on scene that are more reliable; and have the right equipment. People are not wasting time. Before TRIP it may take a tower a long time to get there and there were plenty of times I have worked the road and asked for large wrecker - but they come in without the right equipment thinking they can get the crashed vehicle out.

Or, you call one out there, something happens, equipment breaks; and they have to call another mutual aid wrecker."

On-Scene Activities

- Were there any issues with on-scene communication with VDOT or towing vendors? Can you think of any ways to improve them?

  "It is flowing very well. Kudos to VDOT. They arrive quickly and take communication with towers. I don't have to be number 1 on the scene for hours and hours. We are organized now with the TRIP program. The troopers - the amount of exposure they have had with secondary crashes, people not paying attention to the crash scene, it is very dangerous. We do everything we can to posture our guys. It was not uncommon for a tractor trailer to flip over and troopers could be out there for 5-6-10 hours. We have to reroute traffic and secondary crashes are common. Our troopers getting involved with secondary crashes had gone up before. This has gone down now. With the incentive-based program, these guys have been doing great."

  "VDOT did a good job training the companies on equipment and manpower to meet our needs. When the first tower shows up, they know to approach the tower. Trooper knows very well to make sure that the three truck units are present. As soon as VDOT arrives, give them a quick summary of the status, and whether all vehicle units have arrived. It is working really well. I am a big supporter."

After-Action Reviews

- What is your opinion of the monthly meetings and after-action reviews?

  "The lessons learned coming out of the meetings really benefited the industry. They were prepared to deal with unknown variables much better. I have not heard anything negative. That's a good sign. I think VDOT has done a great job. I call it their program. We might have been involved in some meetings but VDOT really took control."

Incident Management Culture

- Have you noticed a change in culture with towing response and recovery in general?

  "Companies that are part of TRIP are more aware of their responsibilities of arriving in a timely manner. VDOT did the training and I am seeing an upscale in professionalism. If you are held to a higher standard, you act that way. There is an expectation we want out of them. They were told that. They show up with great attitude."

General Impressions

- What are your general impressions of TRIP?

  "TRIP really makes a big difference and turned out very well. It has a lot to do with training towing companies and what equipment is needed. We see lot more positives than negatives. There is not a day that goes by that there is not a horrific commercial vehicle truck crash. We have become more proactive with locations that have these big crashes, like letting trucking industries know the hotspots. TRIP lets us be proactive instead of being typical reactive for incident management. I am a full supporter. We are opening the highways quicker."

  "Our VDOT partners down here are rock stars. They are so helpful and easy to get to - couldn't do without them. You always have hiccups between agencies. Dispatchers are no different. VSP - we are no different. I think this program has filled all those gaps. The program I think has bonded tow companies, VSP, and the FD (fire department). They (FD) have been to the TRIP meetings and they are supportive."

Areas of Improvement

- Are there areas where the program could be improved?

  "VDOT do something with the mass media and local channels. Perhaps with messages such as - you all are tax payers - this is how we are using them. We are opening the highways quicker."

Towing Vendors

Eight of the 11 towing vendors were interviewed about their involvement with TRIP and were asked questions relating to program development, operations, post-operations, and general impressions.

Program Development

- How did you hear about the initial meeting?

  Most towers were called to a meeting with VDOT and Parsons TRIP managers. A couple of towers were not included in the initial meeting invite. One tower found out about the meeting through a former VDOT employee. Another tower stated: "I think they started the process in February or March and reached out to me in July. I missed all the initial meetings. They are demanding all this equipment and training - and in such a short time. I run a small business and this caused hardship."

- How did you feel, or what did you think of TRIP, going into the program?

  There were mixed opinions from the towing vendors about the TRIP program. A few towers knew the program was coming and were excited to participate. One vendor mentioned that Parsons was "very much qualified to orchestrate the program." Other vendors were more skeptical:

  "First meeting - there were a lot of people that weren't happy about it. I don't know what else could have been done to make it easier for people. It was definitely tough for a lot of people. Having to buy a lot of stuff and spending a lot of money on training - that was a heartburn."

  "I thought they are just springing it on us."

  "It will never work. It is the worst thing I have heard in my life. They are going to run the small guys out. What they didn't understand is you are messing with people's livelihoods. The unknowns - which area we are going to get? You had to buy equipment and do all these things before you figure out the area. I see the reason - if someone does not have the equipment, they need to know that before setting the areas/zones. Looking back I see the reason - but there was apprehension on our part. It was all brand new for Virginia. They said they modeled Florida or Georgia. You can do research but you don't know what to believe or not. Just the unknown what was the scariest part of all."

- Any thoughts on how to improve any of the initial meetings, training, etc.?

  The majority of towing vendors felt that the TRIP program development phase was handled well and didn't have thoughts on ways to improve the process. A couple of towers offered the following suggestions:

  "Giving more heads-up. When you got a whole list of stuff that people need to get, more time will be useful. Most of us stay busy - so more time will be helpful."

  "Continued education, training, and a little more support. It costs us $400-500 for the class and hourly pay (overtime); and also lost time. I trained staff to get the equipment to the scene at $800 to $1000 for each person. Maybe put more money on your supervisor, and get the Fire Department training for someone else. Maybe even a first aid class to include CPR for the operator. Heavy rigging and OSHA stuff - I suggest putting that money on the supervisor. Operators and rollback guys make less money than heavy duty wrecker guys. You train them and they are gone in a month. Supervisors make more money - they stay longer with you."

Operations

Notification.

- How were you notified of a TRIP call?

  All towing vendors indicated being notified by VDOT's Traffic Operations Center (TOC).

- What kind of details did you hear about the crash?

  The majority of towing vendors were very pleased about the communication from the TOC. In rare cases, the TOC provided inaccurate details; however, the towers seemed to understand that the notification and information sharing process was a work in progress, especially in the early periods of the pilot:

  "When they call, they tell you about accident. They have done pretty good homework before they call us. This is great."

  "They are as thorough as they can be. I think that's a work in progress. It's crucial that we get the right information and as much details as possible. Fuel pumping etc. with only 30-45 minutes to mobilize for an incident. If not, it will take more time to get to the scene. I think they are generally good. I think in one incident they had false information."

  "The TOC has been very good communicating as much details as they have."

  "Those people are awesome. Everyone I have dealt with in that office. They call you, give info, ask you if you have any questions, any further assistance, all lanes blocked? Trooper has any info? How to get to the scene? Outstanding how they work."

  "They painted a good picture. I know [the Incident Management Coordinator] working my area. There can't be a more dedicated VDOT employee. He actually cares about the towers. Anyway he can help you, he does and he is only a phone call away. He is awesome. He comes directly to the tow truck guys [on scene] and asks what is needed."

- What is your process after being notified?

  All towers indicated acting immediately, no matter the time of day. Examples of the quick action taken upon notification are:

  "We will hit alert on our radios, and will start placing calls for our guys. We are ready to roll in any minute. If the TRIP supervisor says it's a big mess, I get another guy with the skid steer."

"We run like a building is on fire dispatching guys. We have to start calling our drivers. Everybody immediately heads to the shop to get their equipment or vehicles."

- What if you didn't have the right equipment available? Did it ever happen? If so what did you do?

  All towers responded that needed equipment was always available. One tower elaborated about the collaboration of the TRIP towing community if a situation occurred where equipment was not available: "That has not happened. If it were to happen, I would hang up from TOC and call [another vendor]. All the towers in the TRIP program are very cordial and helpful to each other."

- Are there areas of improvement with the notification process?

  A number of towing vendors indicated that the notification process worked well with the exception of instances where the TOC notified a tower in the wrong zone. All towers indicated a willingness to accept challenges with the notification process as part of "growing pains." One vendor thought having a smart phone app would be helpful. Responses:

  "In my opinion, no. I think that the TRIP supervisor does a wonderful job."

  "The only issue we have had - the TOC is not quite sure whose call it is from mile-marker 81.1 or 81.2 or 81.3. There were a couple of times they called the wrong vendor. A lot of that is growing pains. A couple of times, it happens. Some people get upset but it is what it is."

  "I wish TRIP towers had an app - someone pushed a button when there is a crash. May be more details later. Like old school where an alert goes on their pager or mobile device."

Response.

- What were the response units/vehicles?

  All towing vendors indicated bringing two rotators and a support vehicle. The capacities of the rotators were typically 30- and 50-ton units but some indicated 35- and 60-ton units. If extra equipment was needed, they were typically excavators and/or skid-steer loaders. One vendor mentioned always responding with extra equipment just in case it was needed: "We always bring skid-steer. Don't know if everyone brings their skid steer or not - we do. About 75% of the time, we need it for the incident. If you needed it, you'll get paid bonus. It will take more time to call someone in the shop to bring the skid steer."

- Was there any trouble getting all 3 units activated to respond?

  All towing vendors indicated there were never any issues having the required response vehicles available.

- Any challenges arriving at the incident scene? If there were issues, who did you communicate with? VDOT? VSP? How did you communicate with them?

  The prevailing response from vendors on difficulty getting to a scene was because of traffic, especially if the road is shut down or if there are bridges with no shoulders on the response route. There was disparity with vendors on having the ability to communicate en route. Some towers mentioned having that ability, whereas others mentioned not having that ability. Responses:

  "Traffic is the biggest thing. If there is guardrail and we can't get on the shoulder, then it's hard. I have had that problem only a time or two. If we are stuck in traffic, we can't notify anyone. Most of the time, we have been fortunate. It always worked out. We never came to a situation we could not get there."

  "We have had difficulty on 2 separate occasions. If my last truck is 50 ft from the site, and the FD or PD shuts the road, we get delayed. We communicated with VDOT, but they didn't care. We even called back into TOC."

  "If they close a road because they don't want vehicles to get close, then the road is still closed - but we are needed there to get it to open. Having an escort would be great but we have had the state police stop us from going on the shoulder to an accident."

  "Will be good to have a phone number we can call. We are the last person to be called. There should be a trooper, or someone, helping to get us to the incident scene."

  "I can call TRIP supervisor and ask any questions - normally they have all the information."

Arrival On-Scene.

- When arriving on-scene have you had any issues with staging your equipment?

  All towing vendors indicated having no difficulty staging equipment when on-scene. One vendor elaborated: "Sometimes you may have Fire trucks in the way but it is easily remedied. Sometimes traffic may be coming up close to the scene. Whoever is on scene first, they typically guide others to get to the scene easily."

- When arriving at the scene, who did you first communicate with? Did you have issues finding the IC (incident commander)?

All towing vendors indicated communicating with the incident commander (typically VSP) when arriving at the scene. In some instances initial communication was with the VDOT representative. Examples of supporting responses:

"When we get on scene, it was the incident commander [we first communicated with]. We let him know all three trucks are on scene. He gets the truck numbers and gives us notice to proceed. They come straight to us when we arrive; and ask us about all 3 pieces of equipment. They are pretty good about that."

"We don't have any problem with finding the IC. If one of them is not in charge, we go to the other state trooper. In fact, we got to an incident and cleared it so fast that VDOT had not been there. We know how to get to the incident quickly. We will put the work in motion - sometimes even before the TOC calls. It just has been a very smooth process. It has worked far better than I originally thought. The only people who have problems with this program are the ones who have problems otherwise."

Notice-to-Proceed (NTP).

- Who provides the NTP?

  In most cases, towing vendors mentioned that VDOT is the agency that provides the NTP; however, in some cases, it was the VSP.

- Did you keep track of the timestamp?

  All towing vendors kept track of timestamps including the NTP. The process to document times varied. About one-half of the towers indicated taking screenshots on a mobile device as the preferred method. Some towers preferred texting to their dispatcher, and one tower mentioned keeping track of timestamps on a notepad.

- Any general issues encountered with NTP, and how can it be improved?

  The majority of towers had no issues with the process of NTP. A couple of towers provided commentary on a couple of issues with fuel pumping and civilian activity on-scene:

  "One of the early ones, we didn't know that we needed to pump fuel. We probably weren't as prepared as we thought we were. We were kicked off the site. They didn't have resources to do it so we went back to help them. But we were penalized. We were told that the truck company called the hazmat. I don't think they should be allowed - if we should work together, that's understandable - but they had a different plan. They didn't have the manpower - we had the manpower."

  "We had some issues with some drivers and their friends - we are under strict guidelines to clear the highway. We have to stop and get them in a safe area. Once

you get them there, they don't stay there and then the IC thing goes out the window. On civilian side of things, there has to be strict guidelines."

Recovery and Clearance.

- Is there anything you think you could have done differently to convert unsuccessful TRIPs into successful ones?

  All towers mentioned having instances where some tasks could have been done differently. Responses:

  "Sometimes, you just can't beat the time and it isn't anybody's fault. It's just the particular wreck. If you have something that is holding you up, and you can't beat the time limit, it is just what it is."

  "One of them - it was just stupid. It was trying to do one way. It should have been quicker. Then ended up switching plans. But there's always stuff you can do differently."

  "If we had known 56K lbs was in the box, we would have worked it differently. When my wrecker legs were moving up, I looked at the VDOT guy and said this has more than 20K lbs."

  "There was a pretty big rain storm coming. Truck was leaking fuel and rush hour traffic was starting. I talked to my guys, and looked at pictures. In all honesty, I could have probably shaved 20-30 minutes on that crash but even that would not have put me into 90 minutes. Either leave it in the woods, or just hope you don't get penalized."

- Is there a learning curve? Did you find that you were able to improve clearance times as time went on?

  Towers were unanimous in their ability to learn from prior experiences and improve on clearance times through the pilot. Responses:

  "I think we really have. Not only am I pushing for time, but so are the other guys. I am always about safety and training. I do a lot of behind the scene training - both at my shop, and with WreckMaster. We will go behind scenes when we don't have a busy day, and recreate an accident scene. We are always practicing and trying to meet time. We are definitely doing better now."

  "Yes, it gets better and better with each TRIP call we get. All my guys are looking to how we can improve. I tell them - 2 wreckers don't go anywhere. We want them in place at all times. We don't know when we will get a call. We have to be ready."

"I think the learning curve is a continuous ongoing thing. I am assuming other people do it also - but don't know. I always look at the timeline after the fact to see where we could have done better."

"Yes. Clearance times have improved overall, from all companies, I believe. The more you do, the more you are able to do things differently than how they are typically done."

"The biggest thing is the amount of equipment you have to get in and the best part is you have the equipment right there when you need it. The times are getting better and better. When we first got there, we had 2-3 riggers. Now I have 9-10 riggers. As soon as we get there, every day and every wreck, our times are getting better and better."

"We have learned from these experiences. As our drivers learn, we end up doing things a lot faster."

- Any general issues encountered with recovery and clearance, and how can it be improved?

  The majority of towers did not have issues with the recovery and clearance phase of operations. One vendor said: "No, I really don't. The program works. It really does." There were only a couple of examples provided to improve recovery and clearance activity:

  "Due to the timeframe we had, if we had troopers arguing with us on how to do the job on the scene - lights on trucks went off - better to discuss the details later and not on the scene."

  "I know there's been a lot of talk about First Call Environmental - I don't have a problem with them but others have said they could be late sometimes. The benefit of waiting for them is it gives us more time to evaluate exactly what we have to do. Having extra time is sometimes beneficial to us. It may not always be beneficial to get the road opened faster but we are getting our stuff ready while they are on their way."

Post-Operations

After-Action Reviews.

- Did you attend all meetings?

  The majority of towers attended all of the meetings. A couple of towers indicated missing a couple of meetings but they notified TRIP management of their impending absence.

- What are your opinions of these meetings? Did you learn from others' experiences?

  The prevailing response was that the meetings were a very positive experience; however, one vendor mentioned: "Did not find the meetings helpful usually. I understand they want to have the meetings every month. But if you didn't have a call, it's a lot of time to take out of your busy day." Other responses:

  "Oh yes. Absolutely. Putting crash details up on the scene and learning is good. Other people who are not necessarily getting it done, they see how others have done it for similar accidents. I am the one to go go go - that's my personality. Another vendor sees that, they want to be that. It makes them think differently when they go to the accident scene next time."

  "Learn something new or new idea that may speed up next one, learn from other people's problems. Look forward to going to them."

  "Definitely. There is always more than one way to handle a recovery. Sometimes you don't think about other ways until you hear from others. So learning from other's successes and failures is great."

  "I like the meetings. It certainly gives a view of how everybody is doing their recovery. Certainly if you see something, whoever headed that call, you can ask them and learn from their experiences.

  "Those meetings are the best thing in the world. This TRIP program has brought a lot of towers together. Sometimes you hear about a person - you may think they are bad - it helps if you put a face to a name, and shake their hands. I have more friends now. It is a heck of a brotherhood. I knew the people from nearby zones, but didn't know people from other regions. I know them now and we speak at every TRIP meeting; we call each other over phone."

  "Scott Kapton (TRIP manager) has to do his thing to get the program going. He cares about the towers too - and is not just being tough. He puts on a good meeting. He's a good speaker. He has got a little common sense about it. He doesn't stand up there and mark you down. He may throw out a couple of ideas. If a tower did all he could but didn't make his time, Scott Kapton understands."

Invoices.

- Was the invoice process clear and payment timely?

  The consensus among the towing vendors was that the invoice process was fine; however, at least in the beginning of the pilot program, the payment was not timely. Responses included the following:

"It took a while for the payments probably due to the internal systems with Parsons and VDOT. Chalk it up to growing pains. Lately the process has become more streamlined and our payments have been coming steady."

"The payment was not timely. But it was like money in the bank. I was not concerned. The scene safety and job is what is more important to me than the bonus."

"Timely - no. Our first TRIP call was 8 months into the program and it took 4 months to get our bonus. We are required to send all our information in within 5 days after incident. If not by the first TRIP meeting, we should be paid by the second TRIP meeting."

"Initially, where they were paying for part of training - it took forever to get paid. They made us jump through hoops to get our stuff, but were taking time to pay. Early period. But they have gotten better over time."

"Once we got the growing pains out of the way, I think it is going to be fine. Initially, there were some pains. This is a brand new program."

"What is timely? If you all are okay with 3 months, it can be called timely. My first call was in October and I got paid for it in February. I haven't got paid for anything since then. But we stay busy. It's only the bonus right? If it takes 3 months, I don't care. One thing I like to see is when they do direct payments, some sort of notification would be good. I can call my bank, pull my invoice out and mark it paid."

General Impressions

- Do you feel the TRIP program has changed the overall towing and recovery culture to other crashes?

  The responses from towing vendors were unanimous that the TRIP program has created a positive change to the industry culture:

  "Yes, absolutely. When I have a rotation call, I have the mindset of getting it done in 90 minutes. There was double FedEx truck on 288 - the wheels, tires, the whole 9 yards. Back in the day, I would have thought about it differently. Told state police we will get done in 60-90 minutes."

  "Yes. Trip program made us get equipment on scene. Money spent but same time put us ahead of cleaning wrecks up. Always had proper equipment. Makes things easier. Clarifies everything."

  "Absolutely. I think everyone definitely thinks more about getting that road open a lot faster, even if it is not a TRIP."

"It has changed public perception in terms of professionalism and how uniformly TRIP vendors are dressed, and how they behave."

"I think it has improved the industry. Guys are trained now. In the meetings you are held accountable to what you did. All the other 20 companies are looking at us. It's like a peer review process - why would you do that - or great job. Learning something from others."

"Yes - I think it does. Definitely does for us. It has set a higher standard."

"Yes. Because in my county, where we do recoveries on other roads, we work with the same troopers, PDs. Local PDs are reaping the benefits of the TRIP program."

"If we were expected to clear the accident within 90 minutes, we would have definitely done better in the past although, if not TRIP, I try to save the cargo for the customer. I think TRIP has made it easier for us to use the code sections (hold harmless) that use TRIP program - to get the cargo and vehicle out of the road faster. It doesn't apply to other incidents. If working with the county, we have to work with their rules."

- What are your overall thoughts of the TRIP program?

  A key finding in the interviews was that VDOT and Parsons staff managed expectations as towing vendors indicated numerous times their understanding that growing pains are expected with a new program. As the pilot progressed and issues were resolved or at least discussed in an open forum, towing vendors came away with a positive overall impression of the TRIP program:

  "The way I look at it, what we do with rotation list and TRIP call are night and day. What we do with TRIP call is 100% beneficial for all of us. We are part of the group, we have all come together and know who to speak to. I can't think of anything negative. Everything coming out of TRIP is 100% positive."

  "Sometimes in the past, trooper may be on the phone, and not readily talking with the tower when they arrive on scene. But with TRIP that has changed. Anywhere we can cut 1-2-3 minutes for someone to get off the phone, that is helpful. Limits other crashes down the line."

  "Great thing. Initial thoughts: I was for it from day 1. Old system: Hard time with state police - heavy duty wrecker call list, calling friends. TRIP: no friends, neutral position. Everyone had opportunity. Fly by nights weren't getting in on the list. Towers had to step up to plate. Worth doing."

  "Hardest thing now: getting troopers to recognize a TRIP incident and getting TRIP activated quickly."

"I love it. For lot of different things. It is good for the towing companies. Get road opened faster. Rubberneckers. More crashes - even if only 2 cars. You got to get somewhere 10 min faster than the other guy! I think this is a great program. Can't wait to see it expand to other markets."

"I think it is great although I wish we had more advanced notice. If we get an early morning call, we are not as prepared to jump and go, as it is during the day. Overall, the program is working good. And I think it is doing a good job. As long as you don't cut people's areas and taking work away from people, I think this is good."

"Don't change anything with the TRIP program."

"At the end of the day, I am happy with TRIP. I have bought a lot of equipment - big investment – it's all water under the bridge."

- Are you interested in continuing your participation in the TRIP program in your capacity?

  All towing vendors indicated a willingness and interest to continue their participation in TRIP.

CONCLUSIONS

- *Using conservative assumptions, TRIP improved RCT by at least 50 minutes and had a B/C ratio of at least 9 over a 10-year operational horizon. When the top 61 incidents in the before period vs. TRIP incidents were analyzed, the average RCT showed a statistically significant improvement of 62 minutes per TRIP activation and the average TRT improved by 7 minutes per TRIP activation. The monetized benefits associated with this filtering approach were found to be approximately $1,452,000; however, there were benefit overestimation concerns. When the top 39 incidents in the before vs. after periods were analyzed, the average RCT improved by 50 minutes per TRIP activation and the average TRT improved by 6 minutes per TRIP activation. The monetized benefits associated with this filtering approach were found to be approximately $1,113,000; however, there were benefit underestimation concerns. Based on these two filtering methods, the benefits of TRIP were found to outweigh the costs by a factor of 9.2 (top 61 approach) to 12.0 (top 39 approach) over a 10-year operational horizon. When cargo spill incidents were analyzed, the RCT improved by 96 minutes when before vs. TRIP only incidents were compared and by 110 minutes when before vs. all after incidents were compared; however, small sample sizes and high data variability prevented inferences regarding statistical significance. It should be noted that these benefits are conservative estimates as they included only clearance time improvements on the interstates and did not include delay improvements on surface streets or reductions in secondary crashes.*

- *TRIP was viewed as a success by primary stakeholders. As evidenced by the responses to interview questions, both the VSP personnel and towing vendors viewed the program*

favorably. The VSP personnel witnessed more professional towing operations and more timely removal of high impact, heavy vehicle crashes. Towing vendors felt that the culture of the towing community had improved in terms of the expedited response and clearance protocols for both TRIP and non-TRIP incidents.

- *TRIP's development and operational management was a success. Towing vendors stated that growing pains were experienced; however, TRIP administrators did a good job of managing expectations, as evidenced by responses to interview questions. Towing vendors also indicated that lessons learned throughout the pilot resulted in improved clearance operations over time. Areas of improvement were noted for more timely activation of TRIP incidents and improved invoicing and payment processes.*

RECOMMENDATIONS

1. *VDOT's Richmond District should continue TRIP operations and VDOT's Operations Division should explore opportunities to expand the program to other VDOT districts*. The results of the TRIP evaluation in the Richmond District showed RCT savings compared to the before period, and monetized benefits outweighed the operational costs. Additional studies may need to be conducted to develop guidance on locations that might benefit from a TRIP. Roadway volume-to-capacity ratios, truck percentages, geometries, crash history, and towing capabilities are potential criteria for such guidance.

2. *VDOT's Operations Division should conduct ongoing performance analyses of TRIP*. The approach provided with this evaluation is recommended; however, consideration should be given to the fact that data filtering involves several time-consuming manual processing steps. A helpful tool for evaluations of future TRIP and other safety and incident management implementations is development of average delay costs in terms of dollars per minute by incident type and corridor/region.

3. *VDOT's Operations Division should collect additional incident management data across the state*. To help with performing before-after evaluations of TRIP (or other TIM initiatives), towing dispatch and response timestamps should be collected as a standard practice. This would include developing new VaTraffic features, training staff for data entry, and developing protocols for communication of the dispatch and response timestamps from field staff.

IMPLEMENTATION AND BENEFITS

Implementation

With regard to Recommendation 1, the Richmond District has already committed to continuing TRIP operations in the region and VTRC and VDOT's Operations Division are also engaged in determining next steps for studying the expansion of TRIP to other regions in

Virginia. A task order is currently being administered by the VTRC implementation team with support from the Richmond District to analyze the prospects of expanding TRIP to other districts.

With regard to Recommendation 2, VDOT's Operations Division has started conducting year-over-year performance analyses for the Richmond District to augment Figure 13 in this report. For additional TRIP implementations in other districts, the Operations Division will conduct performance analyses within 12 to 18 months of program initiation. VTRC will assist with developing dollar rates per minute of incident duration for different types of incidents as needed.

With regard to Recommendation 3, VTRC has been working closely with VDOT's Operations Division regarding improvements needed in VaTraffic for capturing new data. The Operations Division will communicate with all VDOT districts about the need to implement this recommendation within 2 months of the publication of this report.

Benefits

With regard to Recommendation 1, the benefits of TRIP are documented in the literature and shown, with this study, in VDOT's Richmond District where the benefits outweighed the costs by a factor of 9.2 to 12.0. It should be noted that these benefits are conservative estimates as they include only clearance time improvements on the interstates and did not include delay improvements on surface streets or reductions in secondary crashes. Improving the operational efficiency of existing roadway capacity is a worthy investment for VDOT and is supported as one of the goals in the current VDOT business plan: Ensure Efficient Highway Operations.[16] As part of this goal, and to address existing mobility challenges, the business plan states: "We will utilize field expertise to share best practices and implement enhancements that maximize use of resources to attain mobility goals." Refining and expanding TRIP statewide is specifically noted in Subsection 4.5 as an initiative.

The success of the TRIP pilot in the Richmond District also depended on considerable investment by the towing community in their equipment and training with the trust that they could recover that investment. Continuing and strengthening TRIP operations will further enhance that trust among the first responder agencies. As evidenced by responses to interview questions, both the VSP personnel and towing vendors viewed the program favorably. The VSP personnel witnessed more professional towing operations and more timely removal of high impact, heavy vehicle crashes. Towing vendors felt that the culture of the towing community had improved in terms of the expedited response and clearance protocols for both TRIP and non-TRIP incidents.

With regard to Recommendation 2, towing vendors indicated that lessons learned throughout the pilot resulted in improved clearance operations over time. Documenting the performance of TRIP will help identify these types of improvements and shows the value of the program to stakeholders for securing future funding.

With regard to Recommendation 3, collecting the mentioned data elements consistently over time is essential for conducting objective and timely before-after evaluations. Collecting these data elements will enhance the ability to conduct the performance analyses mentioned in Recommendation 2.

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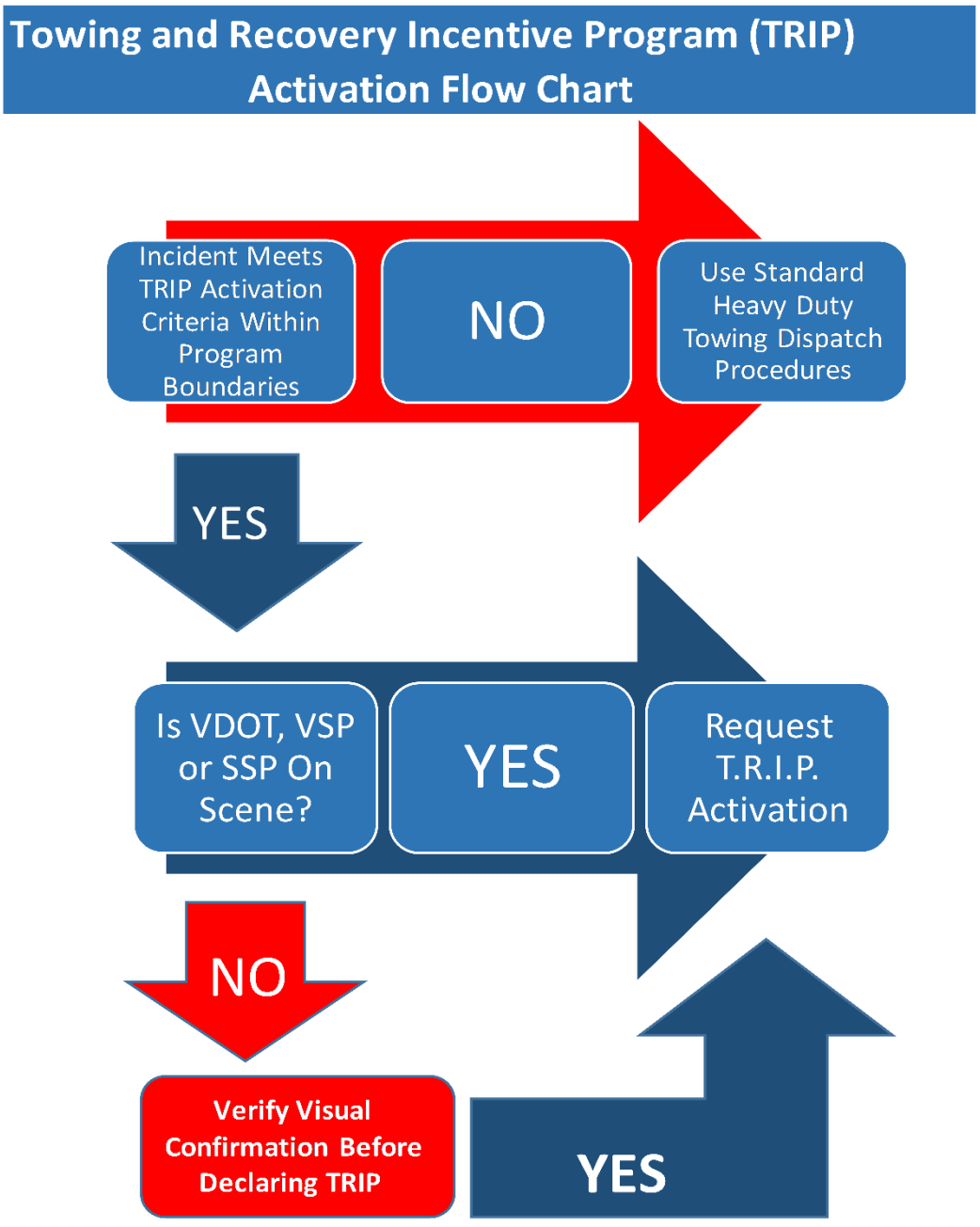
APPENDIX A

TRIP ACTIVATION CRITERIA

TRIP ACTIVATION CRITERIA	
	WHEN SPECIFIC DESIGNATED VEHICLE TYPES ARE INVOLVED IN INCIDENT TYPES LISTED BELOW AND INSIDE THE BOUNDARIES OF THE PROGRAM… ACITVATE TRIP!
	Vehicles- DOT Class 5, 6, 7 and 8:
☑	Truck Tractor Semi-Trailer Combinations
☑	Trucks over 26,000 lbs. or Bobtail Tractors
☑	Large Motor Homes (40'+) or Motor Coaches
☑	Busses
☑	Aircraft (Activate in any incident involving aircraft)
	Incident Types:
☑	Rollover blocking any travel lanes
☑	Multiple Truck Crash
☑	Jack-knifed and not driveable
☑	Lost load on or affecting travel lane(s)
☑	Load shifted on or affecting travel lane(s)
☑	Lost Tandems/ axle or buckled trailer affecting travel lane(s)
☑	Fire affecting the structural integrity of the tractor or trailer
☑	Major impacts with guard rail, bridge structure, or barrier wall
	TRIP Boundaries:
☑	I-295 Entire Length
☑	I-95 from Exit 92 (Ashland) to MM 34.7 (Sussex County Line)
☑	I-195 (Interstate Section Only)
☑	I-64 from Exit 167 (Hanover Rd) to MM 225.0
☑	I-85 from I-95 to MM 40.2 @ Dinwiddie County Line

APPENDIX B

TRIP ACTIVATION FLOW CHART



TRIP ACTIVATION PROCEDURES:
1. DISPATCH OR CALL RICHMOND T.O.C. TO DECLARE TRIP
2. CONFIRM THAT VSP OR OTHER LOCAL DISPATCH IS **NOT CALLING ANOTHER TOW COMPANY**
3. VERIFY CORRECT AUTHORIZED TRIP TOWING FIRM HAS ARRIVED ON SCENE
4. COORDINATE TRIP ACTIVITIES WITH INCIDENT COMMANDER AND TRIP SUPERVISOR

APPENDIX C

DISCUSSION OF VEHICLE HOURS OF DELAY

VHD was initially considered as an important performance measure for the TRIP evaluation; it was expected to quantify the impact of incident duration and TRIP on motorists. However, several data and methodological concerns were identified during the analysis phase such that the VHD metric was later discontinued. These concerns and their underlying causes are presented in this appendix for completeness and for potential mitigation in future studies.

Data Sources for VHD

VDOT procures probe-vehicle-based traffic speed data from INRIX for all roads covered by their networks in the entire state. The RITIS Probe Data Analytics (PDA) Suite is VDOT's gateway to the 1-minute, Traffic Message Channel (TMC)-based average travel speeds procured from INRIX. TMCs are defined for many roadways including all interstates. RITIS PDA Suite also provides a platform for estimating vehicle delay costs based on the probe-vehicle-based traffic speeds, AADT, truck and passenger vehicle percentages, and hourly cost rates for trucks and passenger vehicles. VHD was estimated using RITIS and custom scripts by VDOT's Operations Division.

RITIS provides VHD aggregated temporally (by the hour) and spatially (by interstate segment). Temporally, the hours of incident lane closure (T_1 to T_5) and an additional hour were considered for analysis. For example, if an incident starts at 5:05 AM and the roadway is cleared by 7:40 AM, the hours 5, 6, and 7 are included as incident hours for VHD calculation. Hour 8 (corresponding to the period 8 to 9 AM) is included for calculating VHD for queue clearance.

Spatially, the segment where the incident occurred and its immediate upstream segments (averaging around 10 miles) were considered. The definitions and rationale for using VDOT-defined interstate segments, upstream segments, and 1-hour time period beyond the incident hour for calculating VHD are documented by Lan et al.[3] Traffic volumes used in RITIS VHD calculations were based on AADTs provided by VDOT's Traffic Engineering Division.

Sensitivity Analysis of VHD

The following two sensitivity analyses using the VHD metric were agreed upon by the research team and the field experts:

1. Instead of the additional 1 hour beyond the incident clearance timestamp for analysis to account fully for traffic queue dissipation, try +2 and +3 hours.

2. Instead of 10 miles of upstream spatial segments, try +12 or +15 miles.

VHD Results and Discussion

The VHD analysis results from the first 6-month analysis of the TRIP pilot are presented in Figures C1 and C2. Figure C1 shows the results from all TRIP and TRIP-eligible incidents from the before and after period years for the same 6-month period to account for seasonal traffic and weather patterns. Figure C2 shows the results from the top N TRIP incidents for the same time periods. These scatter plots of VHD and RCT reveal that the correlation between the two metrics is very weak. The main reason for this weak correlation is the variation in traffic volumes at any location by time of day and day of week and how the volumes compare to the available capacity. For two incidents with the same RCT and same location, for example, one during the peak period and another during the night, VHD can be very different owing to the traffic volume variations. In Figure C1, an incident with an RCT of 850 minutes has no delay whereas an incident with an RCT of 45 minutes has 10,000 hours of total vehicle delay. Therefore, a reduction in RCT, an inherent feature of TRIP, may not reflect strongly when VHD is analyzed, especially when the sample sizes are small. As seen in the sensitivity analysis of RCT benefits in the body of the report, even removing one incident in the before or after period considerably alters the observed benefits from TRIP. For the same reason, depending on whether one additional incident in the before or after period occurs in the day or night period will considerably alter any observed VHD benefits.

A second observation from these scatter plots is the inherent high variability in VHD. Although the RCT benefit at each TRIP-activated incident was directly attributable to the TRIP specifications and goals, the same rationale could not be extended to VHD.

It is also noted that the VHD calculations within RITIS use AADTs and national average day of week and time of day traffic volume profiles. RITIS cautions users that these underlying assumptions may be acceptable for aggregate statistics for a large region and not for individual incidents, weather events or holidays, when the traffic may be quite different from the "normal" or "typical" patterns. Again, given the high sensitivity of the TRIP benefits to the small sample sizes, the VHD calculation methodology using RITIS was deemed inappropriate for evaluation purposes.

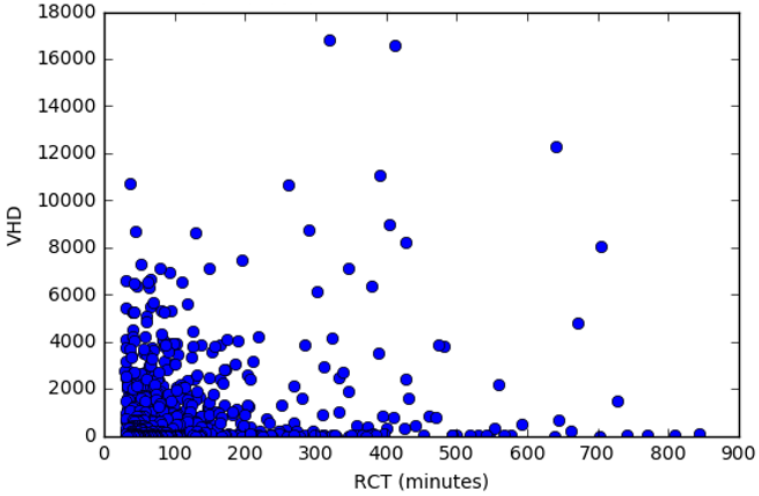


Figure C1. Scatter Plot of Vehicle Hours of Delay (VHD) With Roadway Clearance Time (RCT).

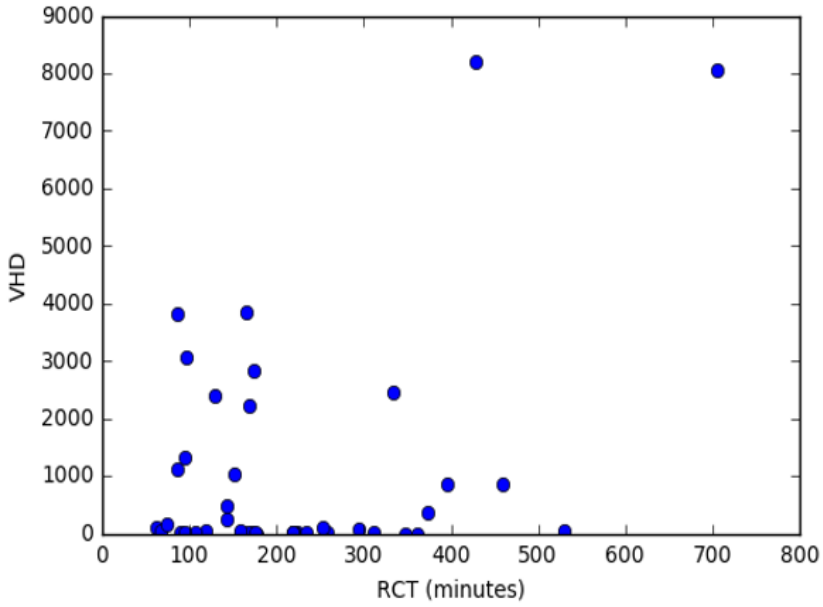


Figure C2. Scatter Plot of Vehicle Hours of Delay (VHD) With Roadway Clearance Time (RCT) for Top N TRIP Incidents. TRIP = towing and recovery incentive program.

Table C1 shows the distribution of incidents by day of week and time of day across different periods after the disabled vehicle filter was applied. As the number of incidents varies from one year to another, ensuring an even distribution across these different temporal groups is quite difficult.

Table C1. Day-of-Week and Time-of-Day Distribution of Crashes After Disabled Vehicle Filter Applied

Period	Day of Week / Day-Night (6 AM-9 PM)				
	Weekday		Weekend		
	Day	Night	Day	Night	Total
2015	93	28	19	12	152
2016	96	36	10	7	149
2017	93	39	12	13	157
2018 (TRIP)	30	15	9	7	61
2018 (non-TRIP)	85	29	15	12	141
Total	397	147	65	51	660

TRIP = towing and recovery incentive program.

Summary

Overcoming the data and methodological concerns presented in this appendix to use VHD directly as an evaluation metric was beyond the scope of this study; however, the details presented in this section may be useful for future research studies.

APPENDIX D

TRIP SYNOPSIS REPORT FORM

VDOT TOWING AND RECOVERY INCENTIVE PROGRAM (T.R.I.P.)

T.R.I.P. CRASH SYNOPSIS REPORT

DATE:	LOCATION:
EVENT #:	TRIP FIRM:

TRIP COORDINATOR/ INCIDENT COMMANDER:

NOTIFICATION TIME:	NOTES:
ARRIVAL TIME:	
NOTICE TO PROCEED TIME:	
WORK STOPPAGE TIME:	
WORK RESUME TIME:	
LANE CLEARANCE TIME:	

ACCIDENT DESCRIPTION

SPECIAL PROBLEMS

SOLUTIONS

Report Prepared By: Signature:

APPENDIX E

TRIP-ACTIVATED INCIDENTS IN YEAR 1

Table E1 details all of the TRIP-activated incidents in Year 1 of the pilot. Of the 72 total incidents, 4 were canceled, 47 were successful, and 21 were unsuccessful. Of the unsuccessful TRIP incidents, 3 were due to arrival past the specified times in the contracts, 2 were due to improper vest usage, and 16 were due to lanes not being opened within 90 minutes of the NTP. Of the 47 successful TRIP incidents, 17 towers received an additional bonus of $1,000 for being asked to bring additional equipment needed for clearance.

Table E1. TRIP-Activated Incidents in Year 1 With Details

No.	Date	Route	Location	Incident No.	Notes[a]	Payout
1	12/27/2018	95	SB MM 52	249481689	Successful	$2,500.00
2	1/3/2018	295	Ramp to 360	257307995	Successful	$3,500.00
3	1/13/2018	85	SB MM 55	267930089	Successful	$2,500.00
4	1/27/2018	95	SB MM 80.3	283710440	Unsuccessful; Arrival Time	$0.00
5	1/30/2018	295	Ramp to 64 E	287427135	Successful	$3,500.00
6	1/30/2018	95	SB MM 52	287143888	Unsuccessful; Open lanes	$0.00
7	2/5/2018	64	WB MM 186	293914883	Unsuccessful; Open Lanes	$0.00
8	2/9/2018	85	MM 44.5 NB	299085339	Successful	$2,500.00
9	2/9/2018	64	EB Exit 197B	298379824	Unsuccessful; Open lanes	$0.00
10	2/9/2018	295	NB MM 44.5	298691406	Successful	$2,500.00
11	2/11/2018	95	NB MM 82	301455543	Successful	$2,500.00
12	3/1/2018	85	NB MM 65	321486170	Non-Successful; Vest	$0.00
13	3/9/2018	85	NB MM 54	332058594	Successful	$2,500.00
14	3/10/2018	95	NB MM 84	333390405	Successful	$2,500.00
15	3/12/2018	295	NB MM 41	335382904	Successful	$3,500.00
16	3/29/2018	195	MM 2.1	356200045	Unsuccessful; Open Lanes	$0.00
17	4/1/2018	85	MM 48.8	358693206	Unsuccessful; Open Lanes	$0.00
18	4/10/2018	95	SB Exit 45	373879677	Unsuccessful; Open Lanes	$0.00
19	4/12/2018	85	SB Exit 63A	378538924	Successful	$3,500.00
20	4/17/2018	64	EB MM 167	386407288	Unsuccessful; Open Lanes	$0.00
21	4/26/2018	85	SB MM 63	399694441	Unsuccessful; Open Lanes	$0.00
22	4/28/2018	295	Exit 53B	402593409	Successful	$3,500.00
23	5/18/2018	295	SB MM 45	429355940	Successful	$2,500.00
24	5/19/2018	95	NB MM 40.5	430615723	Successful	$2,500.00
25	5/19/2018	95	SB MM 52	430739430	Successful	$2,500.00
26	5/20/2018	295	SB MM 37	431390955	Unsuccessful; Open Lanes	$0.00
27	5/26/2018	295	SB Exit 28A	438702217	Successful	$3,500.00
28	5/29/2018	95	SB Exit 50	442511279	Unsuccessful; Open Lanes	$0.00
29	5/30/2018	95	NB MM 41.3	444189022	Successful	$3,500.00
30	5/31/2018	64	EB MM 203.5	445544709	Successful	$3,500.00
31	6/2/2018	295	NB MM 39	447980052	Unsuccessful; Arrival Time	$0.00
32	6/18/2018	95	NB MM 74.8	466759119	Successful	$2,500.00
33	6/20/2018	95	NB MM 82	468967831	Successful	$2,500.00
34	6/21/2018	95	NB MM 75	469854995	Successful	$2,500.00
35	6/22/2018	95	SB MM 46	470788647	Successful	$2,500.00
36	6/23/2018	95	SB MM 51	473017331	Successful	$3,500.00
37	6/28/2018	95	NB MM 51	478342266	Successful	$3,500.00
38	7/2/2018	95	SB MM 85.5	483275426	Successful	$3,500.00
39	7/6/2018	85	SB Exit 67.5	488792053	Unsuccessful; Open Lanes	$0.00

40	7/16/2018	295	NB MM 34	500038006	Unsuccessful; Open Lanes	$0.00
41	7/22/2018	85	NB MM 61	507179034	Successful	$3,500.00
42	8/20/2018	85	SB MM 52	544520361	Successful	$2,500.00
43	9/10/2018	95	SB MM 83.9	568543351	Successful	$2,500.00
44	9/12/2018	64	WB MM 219	570492395	Successful	$3,500.00
45	9/19/2018	95	NB MM 70.4	579511118	Successful	$2,500.00
46	9/22/2018	295	NB MM 35.7	582431435	Unsuccessful; Open Lanes	$0.00
47	9/28/2018	95	SB MM 74.6	596268838	Successful	$3,500.00
48	10/6/2018	95	NB MM 72	620089832	Successful	$2,500.00
49	10/11/2018	95	SB MM 51.6	633795601	Successful	$2,500.00
50	10/11/2018	295	SB MM 39	636204030	Successful	$2,500.00
51	10/12/2018	64	EB MM 181	639722440	Unsuccessful; Open Lanes	$0.00
52	10/15/2018	95	288 Ramp Exit 62	647297981	Successful	$2,500.00
53	10/26/2018	295	SB MM 4.5	694927647	Successful	$2,500.00
54	10/30/2018	64	WB MM 192	707355391	Unsuccessful; Arrival Time	$0.00
55	11/1/2018	295	NB Exit 22	713049302	Successful	$2,500.00
56	11/6/2018	64	EB MM 173	727342252	Successful	$3,500.00
57	11/7/2018	64	WB MM 209	730168849	Successful	$2,500.00
58	11/11/2018	295	SB MM 25	742217806	Unsuccessful; Open Lanes	$0.00
59	11/11/2018	64	WB MM 219	742333529	Successful	$2,500.00
60	11/12/2018	64	EB MM 178	748224044	Successful	$2,500.00
61	11/12/2018	64	EB MM 178	748224044	Successful	$2,500.00
62	11/15/2018	95	SB MM 81	N/A	Canceled	$600.00
63	11/16/2018	295	SB MM 20	758067238	Unsuccessful; Open Lanes	$0.00
64	11/19/2018	95	NB MM 80	767939962	Successful	$3,500.00
65	11/20/2018	64	EB MM 203.5	772238387	Unsuccessful; Vest	$0.00
66	11/25/2018	95	NB MM 86	N/A	Canceled	$600.00
67	12/7/2018	95	NB Ramp to 150	N/A	Canceled	$600.00
68	12/8/2018	95	SB MM 92	824803320	Successful	$2,500.00
69	12/10/2018	295	NB MM 43.4	830401306	Successful	$2,500.00
70	12/10/2018	95	SB MM 61	N/A	Canceled	$600.00
71	12/11/2018	95	SB MM 90	834331886	Successful	$2,500.00
72	12/14/2018	85	NB MM 65	843426102	Successful	$3,500.00

TRIP = towing and recovery incentive program; N/A = not applicable.

[a] For unsuccessful TRIP incidents, the causes are provided as Arrival Time, to indicate that the tower vehicles did not arrive on scene within 45 minutes (peak periods) or 60 minutes (non-peak periods); Vest, to indicate some member(s) of the TRIP towing response team did not wear the proper vest; or Open Lanes, to indicate the lanes were not opened to travel within 90 minutes of notice to proceed.