Transportation Operations Center Operator Retention and Workload Mitigation Strategies

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FINAL REPORT

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ABSTRACT

This study investigated strategies to mitigate the workload for and improve the retention of operators at the Virginia Department of Transportation's (VDOT) Transportation Operations Centers (TOCs). The research involved a literature review, interviews with other state departments of transportation, observations of VDOT TOC operations, and interviews with TOC operators and managers. The study found that data fusion tools were not a significant need for operators, but challenges existed with data output systems. Operator salaries were found to be potentially uncompetitive compared with similar industries. Key factors affecting retention included compensation, career growth opportunities, work-life balance, and the lack of acknowledgment of contract employees' roles by the larger department. Recommendations include formalizing a process for operators to report software issues, implementing findings from this study in future staffing contracts, and enhancing the prestige of performance awards. The study concludes that addressing these issues could improve operator morale, reduce turnover, and ultimately enhance the efficiency and effectiveness of TOC operations.

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INTRODUCTION

The Virginia Department of Transportation (VDOT) is responsible for managing major roadways across the state, with real-time management primarily occurring in five Transportation Operations Centers (TOCs). These centers operate 24 hours a day, 7 days a week, responding to various traffic situations, including recurring and nonrecurring congestion, incidents, work zones, and special events. TOC operators simultaneously monitor traffic cameras, computer-aided dispatch (CAD) feeds, radio communications, various sensors, and crowdsourced data from platforms like Google® Maps® and Waze®. In addition, operators interact with police, safety service patrols, and neighboring states while controlling traffic management devices and updating public information systems.

At VDOT's request, this project was initiated to address growing concerns about operator turnover at TOCs. The study aimed to investigate potential solutions to improve staff retention, optimize data management, and enhance scheduling practices. This research was originally proposed to the Virginia Transportation Research Council's System Operations Research Advisory Committee.

Although extensive research has been conducted on workload and fatigue management in fields such as air traffic control (Isaac and Ruitenberg, 1999) and rail dispatch (Martin et al., 2012), a notable gap exists in literature that specifically addresses these issues in TOCs. This study explored how VDOT operators monitor incoming data and the challenges associated with monitoring, tracking, and managing events. This study also investigated the factors influencing employee retention in this unique work environment, considering job satisfaction, career progression, shift scheduling, and compensation. These tasks were accomplished through a review of the literature, interviews with similar state departments of transportation (DOTs), and visits and interviews with operators, supervisors, and managers at VDOT's five TOCs.

The project proposal included a task to investigate options for introducing software into TOCs that could integrate multiple incoming data streams onto a single screen. During site visits, however, researchers observed that nearly all incoming text data, including the CAD feed, were consolidated on the Automated Traffic Management System (ATMS) alert feed, except for email and Microsoft Teams®, which were required to remain on a separate VDOT-owned computer. Researchers did not observe Waze data populating the ATMS alert feed, although the software recognized Waze as a data type that could be filtered. Operators reported limited use of Waze because of poor data quality, and prior studies found that CAD reported incidents faster than Waze in Virginia (Goodall and Lee, 2019). Interviews with other states suggested that data

diffusion was a significant issue due to a lack of consolidated ATMS data and limited or no CAD data.

Based on these findings, the Technical Review Panel (TRP) elected to eliminate this task and redirect the budgeted hours toward other tasks.

PURPOSE AND SCOPE

The purpose of this study was to identify:

1. Opportunities to reduce mental workload in VDOT's TOCs and methods to prioritize tasks and data sources in order of operational value.
2. Potential real-time data feed fusion solutions for use in TOCs.
3. Best practices to mitigate fatigue, improve job satisfaction, and increase retention for TOC operators.

METHODS

To accomplish the study objectives, the research team performed the following tasks.

1. Conducted a literature review.
2. Interviewed other state DOTs.
3. Observed VDOT's TOC operations and interviewed stakeholders.
4. Developed guidance on best practices.

Literature Review

The research team conducted a literature review to summarize research on the topics of shift scheduling, employee retention, and compensation because they pertain to TOCs or similar fields, such as rail dispatch, air traffic control, and call centers. Researchers reviewed scientific research articles and publications from government agencies, universities, and consulting companies through searches of Google Scholar, the Transport Research International Documentation database (Transportation Research Board, n.d.), and forward and backward citations of relevant articles. Researchers also reviewed Relevant National Cooperative Highway Research Program (Transportation Research Board, 2025) reports and Transportation Management Center (TMC) Pooled-Fund Study (Federal Highway Administration, 2024) reports.

Interviews with Other State DOTs

This task conducted phone interviews with staff at other state DOTs with similar operations centers. The interviews were semi-structured and attempted to answer the following questions.

- What data feeds are used, both internally and externally?
- Which data feeds are of the most value?
- What attempts have been made to fuse data into easy-to-monitor formats, such as screen positioning, audible alerts, or software solutions?
- What evaluations, if any, have agencies conducted on data quality, data fusion, or operator workload?
- What are typical operator pay rates?
- How are operators evaluated based on performance?
- How are round-the-clock shifts scheduled to optimize operator availability, productivity, and job satisfaction?
- What efforts have been undertaken to improve or maintain operator retention?

The purpose of these interviews was to understand the state of the practice and obtain internal insights and information that may not be available in the published literature. Researchers conducted interviews with three other state DOTs based on contacts within the TMC Pooled-Fund Study and the University of Maryland's Center for Advanced Transportation Technology Laboratory's Regional Integrated Transportation Information System program. Interviewees from Maryland, Georgia, and North Carolina DOTs represented staff from technologically advanced DOTs with operational scopes similar to VDOT's.

Transportation Operation Center Observations and Interviews

This task observed typical operations at VDOT's TOCs and interviewed operators regarding their experiences with both typical job duties and shift work.

The research team observed operations at each of VDOT's five TOCs, capturing both high-activity shifts, such as morning and evening peak periods, and low-activity shifts, such as weekday overnights. The visits were conducted at:

- Richmond on September 6, 2023.
- Staunton on October 3, 2023.
- Salem on November 8, 2023.
- Northern Virginia on January 3, 2024.
- Hampton Roads on March 13, 2024.

The purpose of these sessions was to directly observe operator tasks, especially the types of data feeds and rates of information flow. These sessions served as an initial assessment of the types of data that could be fused into a single stream and the feasibility of fusing these data using commercial software. Researchers conducted interviews with available TOC operators,

supervisors, and managers on the same day as the observation visits. These interviews were conducted throughout slow periods during shifts or at designated times before or after shifts at shift managers' discretion. Interviews were semi-structured but attempted to answer the following questions.

- What are the various data feeds, and how are they used in practice?
- Which data feeds are of most value? Does the value of data feeds vary based on the time of day or type of incident? For example, are some feeds more useful during low-volume periods and others more useful during active congestion?
- What aspects of job duties could benefit from data fusion or reducing redundancies? For example, are some data feeds largely redundant? Does the same data have to be re-entered on multiple systems?
- How are shifts scheduled? Example questions include:
  - What is the current shift schedule?
  - How far in advance is the schedule developed?
  - Is shift swapping permitted, and if so, are there any rules around it?
  - How are overnight, day, and weekend shifts distributed among operators?
  - How are shift preferences handled?
- How can shifts best be scheduled to improve job satisfaction?

Developing Guidance on Best Practices

Based on the results of the literature review and interviews with TOC operators, the research team drafted recommendations for operational best practices and shared these draft recommendations with TRP. Based on TRP refinement and feedback, draft results were shared more broadly with TOC managers and operators for additional feedback before finalization.

Guidance was based on best practices from other states and similar industries, such as rail dispatch and air traffic control. Recommendations considered aspects such as:

- Incoming data sources.
- Active traffic management software, that is, output data.
- Compensation.
- Shift scheduling.
- Retention.

RESULTS AND DISCUSSION

Literature Review

The literature review is divided into two sections: (1) retention and (2) scheduling and staffing.

Retention

Das and Barauh (2013) conducted a literature review of employee retention strategies over a broad range of industries. Based on their review of literature, several key factors were found to influence employee retention:

- **Compensation and rewards.** Fair and competitive pay, along with recognition for good work, are important for retention.
- **Career growth opportunities.** Employees value chances for promotion, advancement, and skill development.
- **Work-life balance.** Flexible work arrangements and policies that support work-life balance aid retention.
- **Work environment**. A positive, supportive work culture and physical environment contribute to retention.
- **Training and development.** Investment in employee learning and growth helps retain talent.
- **Leadership and supervision.** Good relationships with managers and effective leadership practices affect retention.
- **Job security.** Employees are more likely to stay when they feel their jobs are secure.
- **Participation in decision-making.** Involving employees in decisions creates a sense of ownership and belonging.
- **Job satisfaction.** Overall job satisfaction is strongly linked to retention.

Das and Barauh (2013) emphasized that multiple interconnected factors influence retention, not just a single element. The authors suggested that organizations take a holistic approach that addresses various aspects like compensation, growth opportunities, work environment, leadership, and so on to effectively retain employees. The review also highlighted that retention strategies should be tailored because different factors motivate different employees. Job satisfaction was found to be negatively correlated with turnover intentions, and improved morale generally leads to lower turnover.

Kossivi et al. (2016) conducted a similar literature review of employee retention to identify key determining factors. The main factors found to influence employee retention were:

- **Development opportunities.** The researchers found that career growth and promotion opportunities were strongly linked to retention.
- **Compensation.** Although some studies showed that pay was a significant retention factor, others found that it had only short-term effects. The researchers noted mixed findings on compensation's impact.

- **Work-life balance.** The study found that flexible work arrangements and policies supporting work-life balance contributed to retention.
- **Management and Leadership.** Supportive management, participative leadership styles, and employee involvement in decision-making were identified as important retention factors.
- **Work environment.** A conducive, flexible, and enjoyable work atmosphere with adequate resources was found to aid retention.
- **Social support.** Good relationships with coworkers and a sense of belonging were linked to increased retention.
- **Autonomy.** The ability to make decisions about one's work was associated with higher job satisfaction and retention.
- **Training and development.** On-the-job training and development opportunities were found to increase employee loyalty and retention.

Similar to the Das and Barauh (2013) study, Kossivi et al. (2016) concluded that employee retention is a complex issue influenced by multiple interconnected factors. The study authors emphasized that more research is needed, particularly on factors like organizational culture and retention differences across employee categories and industry sectors.

Singh (2019) reviewed existing literature on employee retention, with a focus on recent trends. Several common reasons for employee departure were identified, including better pay elsewhere, poor relationships with supervisors, pursuing higher education, family reasons, job dissatisfaction, lack of job security, poor working conditions, and lack of career development opportunities. The study identified key retention strategies that organizations have employed. These strategies included allowing employees to provide feedback and, thereby, fostering effective communication, offering competitive compensation, providing strong leadership, creating career development opportunities, implementing training and development programs, offering work and job flexibility, ensuring job satisfaction, and maintaining fair performance appraisal systems.

Singh (2019) also highlighted recent trends in employee retention practices. These emerging approaches included adopting sustainable human resource management practices, hiring dedicated employee retention specialists, using corporate social initiatives to retain employees, understanding and catering to generational preferences, treating employees as internal customers, considering the employee lifecycle in retention strategies, and adapting to the "gig economy" with more short-term and contract work arrangements.

Martin et al. (2012) examined the relationship between nonstandard work schedules and employee retention in the retail industry. The researchers hypothesized that employees working day shifts or weekday-only schedules would remain with their employer longer than those working nonday shifts or weekend schedules. The study analyzed data from 3,178 unionized retail employees working five different shift arrangements and various weekday and weekend schedules. Using Cox regression analysis, the researchers found support for their hypotheses regarding work schedules. As predicted, employees working nonday shifts or schedules that included weekends remained with their employer for a shorter duration than employees on standard schedules. Specifically, employees on afternoon, mixed, and night shifts had a 43, 87,

and 136% greater rates of turnover, respectively, than day shift employees. Those working weekends had a 70% greater rate of turnover than those working only weekdays.

Martin et al. (2012) highlighted the importance of work schedules in employee retention, beyond the effects of pay and other factors. The findings suggest that organizations should consider the effect of nonstandard schedules on retention when designing work arrangements. The researchers also noted the need for further investigation into the processes by which schedules affect turnover decisions and the potential for alternative schedule arrangements, such as combined day and afternoon shifts, to improve retention while maintaining scheduling flexibility. Significantly, the authors' model predicted that one standard deviation increase in hourly wages was equivalent to a 28% increase in retention rates. In the study, the average salary was $9.70 per hour, with a standard deviation of $2.66.

Burgess and Dale's (2024) study of TOC staffing devoted a section to employee retention. The authors found three main challenges with operator retention: salary restrictions, competition with other industries for entry-level positions, and limited career progression. To address these challenges, the authors recommended using private-sector contractors with the flexibility to provide nonstandard incentives, such as bonuses, recognition, and performance-based pay structures. The use of contractors also expands career progression opportunities because operators may be promoted to senior positions at other DOTs. Agencies may also introduce their own career progression with additional job titles and higher pay for experienced operators. Finally, a more careful selection process may identify the recruits most suited for the dynamic environment of a TOC, further reducing turnover.

Scheduling and Staffing

Bolino et al. (2021) reviewed the literature on nonstandard work schedules. The authors found that nonstandard work schedules can lead to decreased job performance, increased absenteeism and turnover, lower job satisfaction and organizational commitment, and reduced work engagement. To address these issues, the authors suggest increasing schedule predictability and employee control over schedules. Organizations should also conduct regular surveys to assess employee attitudes toward their schedules and prioritize schedule satisfaction because ensuring that employees are content with schedules, regardless of type, can significantly improve morale.

In addition, Bolino et al. (2021) recommended considering individual differences because some employees may be better suited to certain nonstandard schedules than others. A "person-schedule fit" approach could be beneficial when assigning shifts. Leadership adaptation is another key strategy, with managers potentially adopting more trust-based approaches when leading those with nonstandard hours. In some cases, offering higher pay for less desirable shifts might help offset some negative effects.

Gertler and Nash (2004) evaluated staffing levels at railroad dispatching centers to determine the need for on-call relief dispatchers to cover missed shifts. Shifts are organized as three crews working 8-hour shifts during 5 consecutive days. A fourth crew, called the relief crew, covers each regular crew's 2 days off. A fifth crew is on call to cover absences. The

authors estimate a "shift relief factor" between 1.5 and 1.8, meaning that a dispatch center should have between 1.5 and 1.8 times more employees than the number of position-shifts on a given day of operation.

Discussion

The literature suggests that multiple factors influence employee retention, including compensation, career growth opportunities, work-life balance, positive work environment, training and development, effective leadership, job security, and employee participation in decision-making. Studies on nonstandard work schedules reveal their significant effect on job performance, satisfaction, and turnover rates, with employees working nonstandard shifts or weekends showing higher turnover risks. To address these challenges, organizations are advised to increase schedule predictability, consider individual preferences in shift assignments, and potentially offer higher compensation for less desirable shifts.

Interviews with Other States

The research team interviewed representatives from three state TOCs regarding input data, systems, employee compensation, and retention practices. North Carolina, Maryland, and Georgia TOCs were selected for interviews.

Data Inputs

All the states interviewed use video, radio, and phone as sources for detecting traffic congestion. Maryland DOT also monitors Waze, Google Traffic, and the Regional Integrated Transportation Information System (CATT Lab, n.d.) as auxiliary inputs. Maryland does not use a CAD system, instead relying on incoming calls from police for incident notification.

Georgia DOT uses automatic incident detection technology for automatic detection of incidents occurring on video and Carbyne® emergency response software (Carbyne, 2025) for geolocating incoming phone calls. Incoming data are monitored via separate systems, but Georgia plans to procure a new ATMS to integrate separate data feeds onto a single screen.

North Carolina DOT operators have limited use of CAD but must frequently call to confirm events with police because CAD events do not provide adequate information alone. North Carolina considers Google Maps the most useful data stream for incident detection, followed by Waze, stating that Waze is normally the first system to detect incidents. Similar to Georgia, North Carolina plans to procure an ATMS that can integrate these separate data streams into a single feed.

Operator Compensation

Georgia DOT pays starting operators approximately $18 per hour. Operators are managed under a contract with AECOM and evaluated on an annual or semiannual basis. Pay increases for operators are generally awarded on an annual basis.

Starting salaries for operators in North Carolina DOT are also approximately $18 per hour. Operators are managed under a contract with Atkins. Operators are given significant raises after the first year, generally between 4 and 8%. North Carolina is attempting to introduce formalized career advancement paths for operators with new titles and pay bands based on performance and experience. This year is the first in which North Carolina awarded performance-based compensation for operators, with a 6% cost of living raise and an optional additional 2% performance-based raise. Reviews are based on qualitative rather than quantitative metrics. Hours more than 40 per week are paid at 1.5 times the base rate, and all employees are paid 8 hours of holiday pay, with those working holidays eligible for both straight pay and the holiday pay.

Maryland DOT did not provide responses to salary questions.

Scheduling

Georgia DOT operators work rotating shifts unless employees specifically request overnight shifts because overnight shifts are the most difficult to fill. Specific shift requests for certain days are accommodated when practical. Georgia has the ability for operators to work from home as needed, with full access to video and traffic operations systems from TOC laptops. This ability appears to help reduce the number of callouts on short notice because operators with minor illnesses are able to cover shifts from home.

North Carolina DOT operators do not rotate shifts. Instead, they stay on the shift for which they were initially hired. New employees start on the second or third shift because these shifts are the most difficult to fill. First shift (i.e., day shift) vacancies are filled from second and third shift employees. Days off are not standardized but rotate, with work schedules developed approximately 1 month ahead. Short notice callouts are filled by calling available employees. North Carolina has had success in filling schedule gaps by using employees in other regions because operators at any TOC in the state can operate another region's equipment from their own TOC. Operators do not have the ability to work from home.

Maryland DOT did not provide responses to scheduling questions.

Retention

Georgia DOT struggled to fill operator positions as of 2023, but this issue has been improving because of an emphasis on recruiting. Georgia found that an operators' ability to work from home significantly improves retention. Georgia also emphasized employee appreciation, with more explicit discussion of career advancement opportunities and direct communication with Georgia DOT staff rather than AECOM management. AECOM emphasized the importance of employee morale and holding regular family outings, including luncheons and holiday potlucks. Georgia found that recognition from senior Georgia DOT leadership significantly improves morale, and AECOM attempts to communicate all recognition from Georgia DOT directly to operators as soon as possible.

North Carolina DOT also expressed challenges with retention. Efforts to improve morale encompass employee outings, including a recent minor-league baseball game, and recognition of birthdays and work anniversaries. Gift cards were awarded on special occasions, but management paid for these gift cards out of pocket; as a result, these gift cards were typically in the $5 range. New employees were asked to fill out questionnaires regarding favorite snacks and desserts, which management bought for birthdays. Other efforts included onsite holiday parties, such as pumpkin carving contests and chili cookoffs. Operators were given Christmas bonuses, typically between $500 and $1,000.

Maryland DOT did not provide responses to retention questions.

Transportation Operation Center Observations and Interviews

Site visits conducted at VDOT's five TOCs—Richmond on September 6, 2023, Staunton on October 3, 2023, Salem on November 8, 2023, Northern Virginia on January 3, 2024, and Hampton Roads on March 13, 2024—consisted of 3- to 4-hour sessions in the TOC, observing operations and conducting semi-structured interviews with a mix of new and experienced operators and shift managers. In addition, Candice Gibson, from VDOT's Office of Strategic Initiatives, was interviewed for her perspectives as a former TOC manager. To ensure forthright responses, the identities of interviewed operators and managers will not be revealed, and specific comments are aggregated rather than attributed to individual TOC operators and managers.

Data Inputs

VDOT's TOC operators primarily rely on CAD for incident detection. Although the CAD feed has a filter for Waze incidents, this feed is not populated, and operators use Waze as a secondary source if at all. Prior research shows that CAD is generally faster than Waze in Virginia for reporting incidents (Goodall and Lee, 2019). Operators were also required to monitor email for VDOT Customer Service Center (CSC) notifications. Operators continuously monitor video feeds, but the purpose of this task is primarily to gain additional information on known events rather than as a primary source for incident detection. Radio contact with VDOT's Safety Service Patrol and phone calls with police are also used for incident detection, with the Safety Service Patrol providing a significant source of incident detection.

Operators expressed that the amount of incoming information is manageable, especially because most notifications are received via CAD. However, operators expressed frustration with Virginia Information Technology Agency computers because they are the only devices from which operators can monitor email and Microsoft Teams. Operators are automatically logged out of these VDOT laptops after a certain period of inactivity, requiring operators to re-enter usernames and passwords to log back in. Some operators discovered that streaming videos keeps the laptops from logging out and have taken to loading livestreams in a small browser window to force the laptop to remain logged in.

One operator noted that Roadi no longer pushes alerts to the front of the screen in OpenTMS® Version 8. This change limits how much information operators can display on CAD because they need to simultaneously monitor Roadi for information.

Data Outputs

Operators use OpenTMS for most data output because events in OpenTMS can be updated and pushed directly to VDOT's 511 Virginia traffic information system. However, operators expressed several complaints about OpenTMS. For example, the road map underlying OpenTMS is often slow to reflect new road construction, often lagging behind on-the-ground road changes by several years. Similarly, changes in road names are often not reflected in OpenTMS, causing difficulty when entering event coordinates.

Another example given was that some T-intersections in OpenTMS do not recognize locations on the main line opposite the one-leg approach, which appears to be because OpenTMS recognizes only intersections on the T-side of the approach. Hampton Roads specifically struggles with nonstandard facilities, such as active shoulders and movable bridges and tunnels, and claimed to have mover than 30 workarounds in use at any given time to overcome software limitations.

Operators felt that no effective way to address bugs in OpenTMS was available. They perceived that requests for new features and bug fixes were not reviewed. Operators frequently expressed a desire for a formalized system to request and track fixes and new features in OpenTMS.

Operators in Northern Virginia expressed that they would prefer that CSC interact directly with area headquarters rather than running requests through operators. This suggestion was partly due to the additional workload but also due to the difficult interactions with maintenance staff. One employee gave an example of CSC asking TOC staff to tell area headquarters about trees in the roadway. The representative from area headquarters became frustrated, leading to a tense exchange that the TOC staff felt was unnecessary. The operator reported that relationships with area headquarters has improved in recent months, suggesting that any remaining challenges may be attributed to specific individuals rather than systemic issues.

Operators in Northern Virginia expressed significant frustration with Lane Closure Advisory Management System (LCAMS) and work zone data entry. The issue is most prevalent when contractors call in to indicate the start of work zone operations. Often the work zone cannot be found in LCAMS or the VaTraffic software application because of either improper geocoding, or contractors failing to use LCAMS at all. Operators mentioned an upcoming integration of VaTraffic and LCAMS into a new system that may solve some of these problems.

Some operators suggested creating an improved user interface featuring tabs within a single OpenTMS event. Operators must switch between tabs to enter different aspects of a single event, and tab switching in the current version of OpenTMS can be slow and lead to incorrect data entry. Operators mentioned a meeting with the TMS software developer, Q-Free, which occurred prior to the release of OpenTMS Version 8, in which operators expressed multiple

concerns that were never addressed. Operators would also like the ability to open a window for OpenTMS in read-only mode to monitor events managed by other operators.

Compensation

Operators expressed frustration with both low pay and raises that were not in line with inflation. Operators reported earning a starting rate between $17 and $19 per hour at most TOCs, with higher rates of between $20 and $25 in Northern Virginia. Operators felt these wages were not competitive with pay rates of other professions requiring similar skill sets. One operator earning $17 per hour noted that nearby call centers start at $25 per hour. However, operators were generally content with their benefit packages.

Several operators brought up holiday bonuses unprompted. Holiday bonuses reportedly vary by TOC but have been awarded inconsistently if at all. Operators expressed a strong desire for bonuses to be awarded in early December in time for Christmas shopping. Bonuses less than $150 were considered insulting because the actual amount received after taxes is closer to $100. Operators indicated that, when provided, bonuses in the range of $300 to $500 were perceived as more meaningful and effective.

Scheduling

Scheduling practices vary among TOCs. For example, Northern Virginia uses 12-hour shifts, alternating 4 days on and 3 days off one week, then 3 days on and 4 days off the next week, with Friday through Sunday off twice per month. Hampton Roads uses 8-hour shifts, with 5 days on and 2 days off, with the schedule shifting by 1 day to ensure even distribution of weekends. Richmond also uses 8-hour shifts of 5 days on and 2 days off, with operators bidding on shifts based on their audit scores and attendance records. In Salem, the day shift is a mix of 8, 10, and 12 hours to account for different staffing levels for rush hours, and night is strictly 12 hours. Staunton uses 12-hour shifts, with 2 days on, 2 days off, 2 days on, and 3 days off. Shift type preferences vary among operators, but the preference to have predictable and consistent weekends off remained consistent.

TOCs on 8-hour shifts reported difficulty in staffing the second shift during the evening peak period because it is the most active and stressful shift. Because this shift is the hardest to fill, new operators are often assigned to it, leading to new operators feeling overwhelmed and quitting. The overnight third shift was easiest to fill because many operators enjoy the slow pace and the opportunity for other jobs and activities during the day.

TOC managers reported no problems finding staff to work holidays because operators receive 8 hours of holiday pay regardless of whether they work. Those who work holiday shifts receive pay for the hours worked in addition to the 8 hours of holiday pay.

Some operators were unaware of formal policies regarding minimum time between shifts. Other operators thought that the policy was a minimum of 12 hours between shifts but had observed employees getting as little as 8 hours off between shifts.

The process for finding replacement operators when scheduled operators call out sick or are unavailable on short notice is fairly ad hoc. Managers often call or text other operators looking for replacements. This process can be contentious because some operators prefer additional shifts for the overtime pay yet feel these extra shifts are awarded unfairly. Other operators reported having to find their own replacements, which was a significant source of frustration.

Retention

When asked at what point employees are most likely to quit, operators and managers both named two specific times—the first month after completing training and an employee's 1-year anniversary. Interviewees suspected that the first instance—that is, immediately after training—is due to the sudden demands on the TOC floor. Although training is fairly slow and methodical, actual shifts on the floor can be dynamic and stressful, and new operators report feeling overwhelmed. The common practice of assigning new operators to the evening peak-period shift, which is the busiest and least popular, exacerbated this sentiment. Interviewees thought that the high turnover at the 1-year mark may be due to employees expecting significant raises or advancements after a year of service. On realizing that opportunities for career progression are limited, operators begin to search for other jobs. This effect could be mitigated with raises, promotions (e.g., Operator II), or bonuses at the 1- or 2-year marks.

Other

Operators emphasized the value of outstanding service rewards. AECOM uses "Spot Awards"—generally, a $25 gift card—to reward good performance during major incidents or weather events. When awarded promptly and with fanfare, these awards can significantly improve morale. Operators strongly prefer that senior VDOT staff give Spot Awards in front of other operators, either on the TOC floor during shifts or during all-hands meetings. Operators also prefer that Spot Awards be presented as soon as possible following the event precipitating the award.

Nearly all operators expressed annoyance with conference rooms overlooking TOC floors. Operators feel as if they are continually under surveillance. Because most conference rooms are behind the operators, the operators often do not know when they are being observed and are unable to relax throughout entire shifts. As one operator said unprompted, "It's the worst." Operators would like the shades to be pulled down when no conference is occurring and minimal oversight during non-mission-critical meetings.

Operators are keenly aware of their status as contract employees and expressed concerns about VDOT's lack of acknowledgment of contract employees' roles. This feeling varies greatly by TOC, but better communication from VDOT staff is generally likely to improve morale. Operators recalled fondly instances in which senior VDOT staff thanked them personally for excellent performances during critical events. The effect seems greatest when VDOT staff appear in person on the TOC floor to give a short speech and thank each operator individually.

<div align="center">**Develop Guidance on Best Practices**</div>

This section integrates findings from the literature, interviews with other states, and TOC site visits to document best practices to reduce TOC operator workload, reduce turnover, and improve morale. The findings are grouped under five sections: data inputs, data outputs, compensation, scheduling, and retention.

Data Inputs

VDOT has a sophisticated system able to handle multiple data streams in a consolidated format. VDOT operators primarily rely on CAD for incident detection, which has been shown to be faster than Waze in Virginia (Goodall and Lee, 2019). Operators also use video feeds, email notifications, radio contact with Safety Service Patrols, and phone calls with police to manage traffic incidents. Unlike some other states that lack or have limited CAD systems, VDOT's approach seems to be more integrated and effective.

Although other states like Georgia and North Carolina are planning to procure new ATMSs to integrate their data streams, VDOT already has most of its data consolidated in CAD. Furthermore, VDOT operators find the amount of incoming information manageable, indicating that adding a data fusion tool is not necessary at this time.

VDOT should maintain its current CAD-centric system but address some minor issues. These issues include fully integrating Waze data into the CAD feed as a complementary source, resolving timed log-out issues with VDOT-supplied laptops, and evaluating the recent updates to OpenTMS. Although a data fusion tool is not currently needed, VDOT can continue to monitor advancements in traffic management technology and operator feedback to ensure that the system remains effective and efficient. Overall, VDOT's current system appears to be more advanced and integrated than those of the other states interviewed, and VDOT can focus on refining and improving the existing system rather than investing in new data fusion tools.

Best Practices for Data Inputs

- Maintain the current CAD-centric system while addressing minor issues.
- Resolve timed log-out issues with Virginia Information Technology Agency computers.
- Evaluate the effect of recent updates to OpenTMS.
- Continue monitoring advancements in traffic management technology and operator feedback.
- Focus on refining and improving the existing system rather than investing in new data fusion tools.

Data Outputs

Based on interviews with VDOT operators, OpenTMS is a crucial tool for data output and 511 updates, yet the platform has several significant issues affecting operator efficiency and effectiveness. The main problems include outdated road maps, inability to reflect road name changes, difficulties with certain intersection types, and challenges with nonstandard facilities.

<div align="center">14</div>

Operators are also frustrated by the lack of a formal system to report and track bug fixes and request new program features and by issues with the user interface and tab switching.

Given these challenges, VDOT can take a proactive approach to address the OpenTMS issues. VDOT currently has an established process to report bugs to OpenTMS developers. This process could be enhanced to additionally capture requests for new features. VDOT could negotiate a tracking schedule as part of their contract with the OpenTMS developers, ensuring that progress on these improvements is monitored and reported regularly. In addition, VDOT could explore the possibility of creating a user group or advisory committee composed of operators from different regions to provide ongoing feedback and suggestions for OpenTMS enhancements.

VDOT could document and standardize the workarounds currently in use, particularly in areas like Hampton Roads, to ensure consistency across operators. The department could also investigate the upcoming integration of VaTraffic and LCAMS to determine if it can address some of the current issues with work-zone data entry.

A significant challenge for operators involves interactions with CSC and area headquarters, particularly regarding emergency maintenance issues. Operators are often in the position of relaying information from CSC to area headquarters, especially during off hours. This process can lead to tense exchanges, particularly when area headquarter staff become frustrated with the indirect communication chain. The fact that operators may not have accurate phone lists for area headquarter on-call staff exacerbates the situation, which could be remedied by updating on-call phone lists regularly. When interactions are tense, operators can report these interactions to their managers up the chain of command. If needed, District Traffic Operations Managers can intercede.

Best Practices for Data Outputs

- Enhance the bug-reporting process to include the ability to request new program features in OpenTMS.
- Create a prioritized list of issues and desired features to be shared with developers at regularly scheduled intervals.
- Engage VDOT's Operations Technology Division in the process of reporting bugs and requesting new program features.
- Negotiate a tracking schedule as part of the contract with OpenTMS developers.
- Review the current process to ensure that operators feel engaged and formally broadcast the current change management system.
- Create a user group or advisory committee of operators from different regions to provide ongoing feedback.
- Document and standardize workarounds that are currently in use, particularly in areas like Hampton Roads.
- Reevaluate the protocol for escalating communication issues between operators and area headquarters.
- Implement a clear escalation process for operators to follow when faced with difficult interactions related to CSC requests.

- Establish a procedure for the District Traffic Operations Manager to intercede and address issues with area headquarters when necessary.
- Regularly update area headquarter on-call lists for emergency maintenance needs.

Compensation

When asked what single act would reduce turnover, TOC operators nearly always mentioned higher wages. Operators reported starting salaries at between $17 and $19 in most TOCs, with higher rates between $20 and $25 in Northern Virginia. Operators also stated that raises were often very small and not in line with perceived inflation.

The evidence suggests that salaries may be below similar industries. Table 1 shows the most recent data from the Bureau of Labor Statistics (2023a) for May 2023 for similar industries. The wages have been updated for May 2024 based on 3.27% annual inflation of the consumer price index during this period.

Table 1. Hourly Wages for Transportation Dispatchers (Bureau of Labor Statistics, 2023a) and Customer Service Representatives (Bureau of Labor Statistics, 2023b)

Industry	Hourly Mean Wage as of May 2023	Hourly Mean Wage as of May 2024 (3.27% Inflation)
Support Activities for Road Transportation	$18.94	$19.56
Taxi and Limousine Services	$17.05	$17.61
Other Transit and Ground Passenger Transportation	$19.49	$20.13
Urban Transit Systems	$22.68	$23.42
Interurban and Rural Bus Transportation	$22.28	$23.01
Customer Service Representatives	$20.29	$20.95

Another source of data is the website Glassdoor, where users can anonymously submit their salaries. According to Glassdoor (2024) and based on 28 submissions, "TMC Operators" with zero to 1 years of experience earn between $39,000 and $57,000 annually in base pay. Using 2,080 annual hours, this rate equates to between $18.75 and $27.40 per hour.

Two states interviewed provided starting operator salaries, with both Georgia and North Carolina paying $18 per hour. However, both states reported challenges in hiring and retention at these rates.

VDOT may wish to require staffing contracts to establish minimum salaries as a method to improve hiring and retention. The literature shows that increasing salary by $1 per hour may reduce turnover by 6% from current levels (Martin et al., 2012) or 1.3 fewer monthly resignations per 100 employees (Emanuel and Harrington, 2020).

Best Practices for Compensation

- Consider establishing minimum salaries in staffing contracts to improve hiring and retention.
- Implement a structured pay raise schedule that keeps pace with inflation and industry standards.

- Offer competitive starting salaries based on industry benchmarks and regional cost of living.
- Consider performance-based bonuses or pay increases to reward and retain top performers.
- Regularly review and adjust compensation packages to remain competitive with similar industries.

Scheduling

Based on the comprehensive review of literature, interviews with other states, and discussions with VDOT operators, TOCs' scheduling practices may significantly affect employee satisfaction, performance, and retention. The literature highlights the negative effects of nonstandard work schedules, and interviews with Georgia and North Carolina demonstrate varied approaches to shift rotation and callout management. VDOT's TOCs show diverse scheduling practices, each with its own set of challenges, particularly in staffing certain shifts and handling short-notice callouts.

To address these issues, VDOT could develop a more sophisticated system for managing short-notice callouts. This system could involve creating a dedicated on-call role, implementing a fair rotation system for overtime opportunities, exploring work-from-home options during minor illnesses, and leveraging operators from other regions to fill gaps. These strategies could help reduce the stress and frustration associated with the current ad hoc approach to covering unexpected absences.

Furthermore, each TOC could reconsider its scheduling practices to optimize meeting employee needs, including consistent weekends and schedule predictability. This consideration could include increasing schedule consistency, especially regarding weekends off, and implementing a "person-schedule fit" approach to assign shifts based on individual preferences and capabilities. Balancing the workload for new operators by avoiding assigning them exclusively to the most stressful shifts could also help improve retention. Clear communication and consistent enforcement of policies regarding minimum time between shifts are also crucial.

To enhance employee satisfaction and retention, VDOT could conduct regular surveys to assess attitudes toward schedules, consider offering higher pay for less desirable shifts, provide employees more control over their schedules when possible, and implement a more transparent system for shift assignments and overtime opportunities. Improving communication and training is also vital to ensure all operators are aware of scheduling policies and provide managers with best practices for nonstandard schedule management.

Best Practices for Scheduling

- Develop a sophisticated system for managing short-notice callouts.
- Create a dedicated on-call role or implement a fair rotation system for overtime opportunities.
- Explore work-from-home options during minor illnesses.
- Leverage operators from other regions to fill gaps when possible.

- Reconsider scheduling practices to optimize for employee needs, consistent weekends, and schedule predictability.
- Implement a "person-schedule fit" approach to assign shifts based on individual preferences and capabilities.
- Balance the workload for new operators by avoiding assigning them exclusively to the most stressful shifts.
- Clearly communicate and consistently enforce policies regarding minimum time between shifts.
- Conduct regular surveys to assess attitudes toward schedules.
- Consider offering higher pay for less desirable shifts.
- Provide employees more control over their schedules when possible.
- Implement a transparent system for shift assignments and overtime opportunities.

Retention

Research consistently emphasizes that multiple interconnected factors—including compensation, career growth opportunities, work-life balance, and work environment—influence retention. The experiences of Georgia and North Carolina demonstrate the effectiveness of practical approaches, such as work-from-home options, employee appreciation events, and recognition from senior leadership in improving morale and retention. VDOT operators emphasized critical periods for potential turnover, particularly the first month after training and around the 1-year employment mark, due to the challenging transition to floor duties and unmet expectations for career advancement.

Based on these findings, VDOT could enhance the prestige of Spot Awards by ensuring that senior VDOT staff present these awards promptly and publicly. This practice aligns with Georgia's successful practice of communicating DOT recognition directly to operators. VDOT might also encourage more direct communication between operators and VDOT staff, fostering a sense of value and connection to the broader organization. Implementing regular employee appreciation events and incentives—such as team outings, holiday parties, and milestone recognitions—can significantly boost morale. These events could be modeled after North Carolina's creative approaches, including personalized birthday celebrations and seasonal contests.

In addition, VDOT could address the identified turnover risks by implementing a more gradual integration process for new operators and exploring structured career advancement opportunities or recognition programs at key milestones. This process could include a tiered operator system with associated pay increases or responsibilities. Offering work-from-home options, where feasible, could also enhance retention, as demonstrated by Georgia's success. Furthermore, VDOT might benefit from improving communication about career paths and potential growth opportunities within the organization, addressing the concerns that lead to turnover at the 1-year mark. By implementing these strategies, VDOT can create a more supportive, engaging work environment that encourages long-term commitment from its TOC operators.

An important consideration for improving the work environment is addressing operators' concerns about feeling under constant surveillance because of conference rooms overlooking TOC floors. To alleviate this stress, VDOT could encourage managers to consider keeping conference room shades drawn during meetings when direct TOC oversight is not needed.

Best Practices for Retention

- Enhance the prestige of Spot Awards by ensuring that senior VDOT staff present them promptly and publicly.
- Encourage more direct communication between operators and VDOT staff.
- Implement regular employee appreciation events and incentives—such as, team outings, holiday parties, and milestone recognitions.
- Address turnover risks by implementing a more gradual integration process for new operators when transitioning from training to the TOC floor. For example, new operators may start on low-activity shifts and partner with senior operators.
- Explore structured career advancement opportunities or recognition programs at key milestones.
- Consider implementing a tiered operator system with associated pay increases or responsibilities.
- Offer work-from-home options where feasible.
- Improve communication about career paths and potential growth opportunities within the organization.
- Address operators' concerns about feeling under surveillance because of conference rooms overlooking TOC floors.
- Encourage staff to consider closing conference room shades during meetings when TOC observation is not necessary.

CONCLUSIONS

- *Operators do not see the need for data fusion tools.* During site visits, operators did not express the need for any data fusion or visualization tools when prompted. Instead, operators stated that they were able to easily manage existing inputs primarily consisting of CAD, with occasional inputs from radio, CCTV, and email.

- *Data output via OpenTMS is reportedly challenging.* In interviews, operators mentioned difficulty with inputting events in OpenTMS. The common issues cited were outdated maps, outdated road names, and geolocation problems with T-intersections, active shoulders, movable bridges, and tunnels. Although operators have developed informal workarounds, this issue continues to be a struggle.

- *Operator salaries may not be competitive with other industries.* For many operators, the starting salary is between $17 and $19 per hour. Operators cited private-sector call centers as offering higher wages for similar work. Glassdoor reports that TMC operator salaries are between $34,000 and $80,000 per year, or approximately $17 and $40 per

hour. The other states interviewed reported the $18 per hour starting salaries and struggles with hiring and retention.

- *Operators expressed what they perceived as VDOT's lack of acknowledgment of contract employees' roles.* Operators are contract employees, and several expressed a feeling of lacking inclusion within the VDOT community. Specific examples were low-value Spot Awards given long after an incident and with little fanfare, VDOT conference rooms overlooking TOC floors being kept open for longer than necessary, and senior VDOT staff expressing minimal appreciation.

RECOMMENDATIONS

1. *VDOT's Assistant Division Administrator for Traffic Operations and Incident Management should enhance the change management system for ATMS.* Operators and managers have direct knowledge of bugs or missing functionalities in OpenTMS but do not feel the system is responsive to their needs. VDOT can enhance this system by including the ability to request new program features in addition to reporting bugs. VDOT should also include the Operations Technology Division in the process and formally broadcast the change management system so that operators are aware of and more engaged in the process.

2. *VDOT's Assistant Division Administrator for Traffic Operations and Incident Management should ensure that relevant findings from this study are implemented in future TOC staffing contracts.* When the TOC management contract is up for rebidding, VDOT should ensure that it includes the relevant best practices identified in this study as requirements. These best practices may include salary minimums, pay raise schedules, required holiday bonuses, and slower transitions to the floor after training.

3. *VDOT's TOC Managers should implement several changes that could benefit workplace morale.* Operators consistently expressed feeling disengaged from VDOT management. VDOT should consider taking part in opportunities the contractor offers to acknowledge employees, such as actively nominating operators for Spot Awards, awarding them in-person on the TOC floor, and expressing appreciation after successfully managing major incidents. TOC managers should encourage staff to consider keeping shades drawn in conference rooms when TOC observation is not needed.

IMPLEMENTATION AND BENEFITS

The researcher and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and determine the benefits of doing so. This is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

Implementation

With regard to Recommendation 1, VDOT's Assistant Division Administrator for Traffic Operations and Incident Management will begin a process within 1 year of this publication to formally track bug reports submitted by operators and coordinate semiannual calls with the OpenTMS, or other current ATMS, software developer to advise of and track these bug reports. If feasible, VDOT's Incident Management Coordinator should also ensure that future contracts with ATMS providers include mandatory responses to bug reports and feature requests.

With regard to Recommendation 2, VDOT's Assistant Division Administrator for Traffic Operations and Incident Management—before requesting proposals for the next TOC staffing contract or extending the current TOC staffing contract—should ensure that contracts include language to address the findings indicated in this report's "Develop Guidance on Best Practices" section. The Assistant Division Administrator for Traffic Operations and Incident Management will have discretion over which findings are to be included in the contract based on their relative value, feasibility, and relevance.

With regard to Recommendation 3, VDOT's TOC managers will implement within 6 months of this publication the findings indicated in this report's "Develop Guidance on Best Practices" section. TOC managers will have discretion over which findings are implemented and the method of implementation based on each finding's value and feasibility.

Benefits

The benefit of implementing Recommendation 1 is that VDOT may experience improved functionality and user experience in the OpenTMS system. This implementation would address the challenges operators face with data output, such as outdated maps and geolocation problems. By formalizing the bug reporting and feature request process, VDOT can expect more efficient operations, reduced operator frustration, and potentially faster incident response times. This improved communication channel could also lead to cost savings by reducing the need for operators to develop and maintain informal workarounds.

The benefits of implementing Recommendation 2 are the potential to significantly improve operator retention and job satisfaction. By addressing issues such as competitive salaries, pay raise schedules, and holiday bonuses, VDOT could reduce turnover rates and associated training costs. A slower transition to floor duties after training could lead to better prepared operators, potentially reducing errors and improving overall TOC performance. These changes could result in a more stable, experienced workforce, which would likely enhance the efficiency and effectiveness of TOC operations.

The benefits of implementing Recommendation 3 are improved operator morale and motivation. By presenting these awards promptly, publicly, and with senior VDOT staff involvement, operators are more likely to feel valued and recognized for their contributions. This increased sense of appreciation could lead to improved job satisfaction, potentially reducing turnover and increasing productivity. Fostering a culture of excellence encourages operators to

perform at their best, potentially resulting in more efficient incident management and better overall TOC performance.

Evidence in the scientific literature signals that increasing compensation specifically can yield positive returns. A study of customer service representatives of a Fortune 500 retailer found that a $1 increase in hourly pay (at a cost of $1.30 after taxes) resulted in 1.3 fewer monthly resignations per 100 employees for a return of $0.13 (Emanuel and Harrington, 2020). Simultaneously, worker productivity increased after the wage increase, resulting in a productivity return of $1.56. Combining these effects results in a $1.69 return on a $1.30 investment for a benefit-cost ratio of 1.3. Productivity increases and turnover reductions for warehouse workers were similar, with a cost-benefit ratio of 1.35 (Emanuel and Harrington, 2020).

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