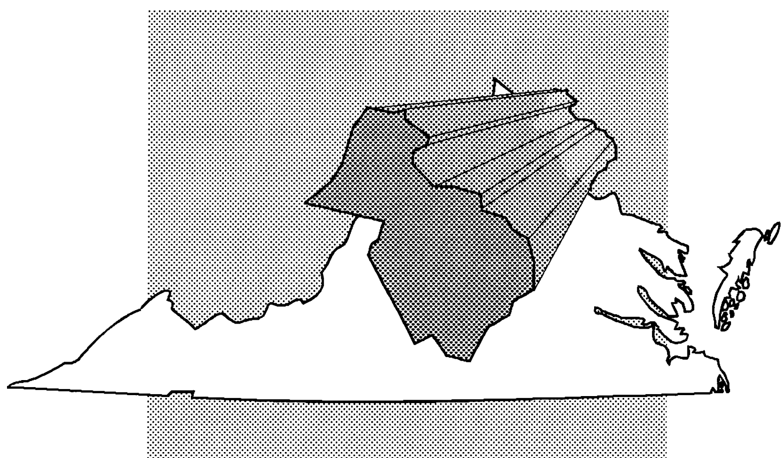
TECHNICAL ASSISTANCE
REPORT

ANALYSIS OF THE CAPABILITIES AND OPERATIONS OF THE NORTHERN VIRGINIA TRAFFIC MANAGEMENT SYSTEM



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PREFACE

This report is the result of a joint effort between Jimmy Chu of the Northern Virginia Traffic Management System (TMS), Charlie Hall of the Central Office, Ysela Llort of the Northern Virginia District, and the authors. Fred Akainwumi, Nagia Dehbi, Marlo Dixon, and Bill Price of the Northern Virginia TMS merit recognition for their assistance.

This report discusses methods of improving operations at the TMS without making major hardware changes. Although this report focuses on the Northern Virginia TMS, the authors believe that the analysis shown herein is applicable to other traffic operations centers throughout the U.S.

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INTRODUCTION

The Northern Virginia Traffic Management System (TMS) is a multimillion dollar operations center serving I-66, I-395, and the Woodrow Wilson Bridge located on I-495 (I-95 and the Beltway). The TMS has a significant amount of equipment at its disposal: closed circuit televisions (CCTV), loop detectors located on I-66 and I-395, changeable message signs (CMSs), and a Perkins-Elmer minicomputer system. The software that controls this system provides some automatic capabilities: for example, it activates audible and/or visual alarms when traffic increases beyond normal levels, when a piece of equipment fails, or when a CMS change is required. TMS operators have numerous responsibilities including incident detection and verification, notification of the proper parties for incident response, signing on I-66 and I-395 during normal and abnormal traffic conditions, control of the reversible HOV lanes on I-395, and signing operations involving the Woodrow Wilson Bridge.

Most of the TMS equipment has been in operation for nearly a decade. Many of the components, such as the loop detectors and the associated communications units, have reliability problems. This results in several procedures being performed manually even though they have been designed to be performed automatically. Furthermore, other components have been added since the system's inception in 1985, and since certain pieces of hardware are not compatible with one another, the TMS is not a fully-integrated system. These problems are compounded by the possibility that operators can be overwhelmed with telephones ringing, alarms sounding, monitors showing congestion, detectors failing, and requests for technical assistance from the incident removal teams. Clearly, full utilization of the TMS's automated capabilities are necessary to achieve the TMS's full potential.

PURPOSE AND SCOPE

The objective of this project was to determine how TMS operations may be improved by making modifications to the existing system. Procedural modifications and minor software changes were within the scope of this project. However, major hardware changes, such as the installation of a new communications system, were beyond the project's scope.

METHODOLOGY

A five-person interdisciplinary team studied the TMS through observing operations at the TMS, interviewing TMS operators, and examining documentation on the Northern Virginia TMS and other similar traffic management systems. Specific improvements were developed in two basic categories: (1) system improvements, which focus on improved field equipment and software, and (2) human factor improvements, which focus on enhanced operational procedures.

RESULTS

The fact that the TMS is primarily a manual system places a heavy load on its operators. Equipment failures render many of the automatic capabilities useless, which has forced the operators to rely heavily on the manual features of the system, such as cameras and phone calls coming into the TMS. Failures among the remote control units (RCUs), coaxial cable links, and the loop detectors result in inaccurate data being provided to the TMS's software, which means that the TMS's automatic incident and congestion detection capabilities are not reliable. The slow speed of the computer system and the communications between that system and equipment in the field also hampers the TMS's operations.

To their credit, the TMS's operators manage to perform their duties without being able to rely on accurate traffic data from loop detectors. Instead, the video monitors and telephone calls are their primary source of information to maintain the ramp metering on I-395, operate the signs and gates on I-395, operate the signs for I-66 and the Woodrow Wilson Bridge, monitor the cameras to check for incidents, congestion, and ramp queues, update the computer-generated traffic map, maintain contact with police forces, the media, and the Safety Service Patrol, and handle equipment failures.

RECOMMENDATIONS

The TMS is clearly an old system. In order to take advantage of advances in electronic technology, VDOT should consider replacing the computer and communications systems in the near future. However, this study has developed a number of sound recommendations to improve the operations of the existing system. Implementation of these recommendations should show immediate benefits. As cost is a prime consideration, these recommendations have been prioritized by dividing them into three categories. Recommendations categorized as "*Essential*" need to be implemented if the TMS is to perform more than mere video monitoring (i.e., use the advanced automated features such as incident and congestion detection). Failure to implement these essential recommendations will result in the TMS functioning as a manual system regardless of future improvements. Recommendations categorized as "*Important*" would greatly enhance the TMS and are ranked in their order of importance. Finally, recommendations categorized as "*Worth Considering*" should be implemented as resources become available. These suggestions are also listed in their order of importance. The TMS operators should be given primary consideration when reviewing these recommendations. They run the system, hence their input is essential.

Finally, it is the authors' understanding that efforts to implement some of these recommendations are already underway, and we have noted this in the report where applicable.

1. It is *essential* that the following recommendations be implemented if the TMS is to be anything beyond a manual system. If resources are not available for the recommendations listed in this category, the TMS cannot take advantage of its software and hardware capabilities even with the installation of a state-of-the-art computer system.

   - *Replace the faulty detectors.* Obtaining good data should be the highest hardware priority: all software is useless if the detectors that feed that software are faulty. Approximately 200 detectors are currently listed as hardware failures; this list is updated every two weeks. These detectors should be repaired or replaced. *This work was completed in the Fall of 1993.*

   - *Provide the TMS three months advance notice of construction/maintenance that will occur on I-395 or I-66.* Milling (and other kinds of maintenance) can destroy as many as 20 loop detectors in a 24-hour period. It is essential that the detectors be replaced immediately. A contract for loop detector replacement requires roughly three months to arrange. Therefore, three months notice should allow the TMS to promptly replace destroyed detectors.

- *Replace the Remote Control Unit (RCU) system.* There are 45 RCUs in the field, 4 of which are failing due to hardware problems and 8 of which are failing because of software difficulties. These RCUs must be custom made, and it is not possible to replace them one at a time. The TMS has to either operate with some bad RCUs or upgrade its entire RCU system. An upgrade would entail:

  — replacing the 45 RCUs

  — replacing the CCU, which is the central communications unit that allows the Perkins-Elmer software to receive data from the RCUs

  — modifying the Perkins-Elmer computer software so that it will be compatible with the new RCU system

  Replacing the RCU system would likely be cost-effective in the long run for two reasons: (1) the new RCU system should be compatible with a future upgrade of the TMS's communications system, and (2) replacement RCUs could be bought from a supplier rather than being custom made.

If the above changes cannot be made, then the CMS operations should be removed from the Perkins-Elmer System. The operators cannot depend on the software system to correctly activate the proper signs except the pretimed regulatory (HOV) messages on I-66. All CMS operations could be controlled by a personal computer if a method were developed to allow more than one sign to be changed at a time with a personal computer. At this time, when the Perkins-Elmer system is disabled, only one sign may be changed at a time. With over 100 signs in operation, the TMS would need to be able to change groups of signs at once. *This option should also be considered if the CMS messages cannot be changed from "CONGESTION IN X MI".*

2. The following recommendations are *important* and would greatly enhance the TMS. They call for altering certain software subroutines, which would require the assistance of a qualified computer programmer or consultant. However, these added features would make much better use of the TMS's capabilities and would lighten the load on the TMS operators. These recommendations are ranked in order of importance.

   - *Automate software resets of nonphysically failed detectors.* There are two types of detector failures: hardware failures, where the detector has failed in the field, and software failures, where the detector is working in the field but has a communications error with the software. Currently, operators must reset *all* detectors at once, including those that have failed in the field, or they must reset each detector individually. The former practice results in frequent false alarms, and the latter is a time consuming process. A software subroutine should select detectors that have not failed in the field but which are giving bad information, take them off-line, and then put them back on-line (i.e., reset them). If such a subroutine is not feasible, then the next best improvement would be separation of the failed detectors into hardware and software categories as they appear on the screen.

- *Automate software resets of non-physically failed RCUs.* This recommendation follows the same logic as the one above. A software subroutine to reset RCUs is needed.

- *Change the CMS message warning drivers of traffic delays to "CONGESTION BETWEEN EXIT 5 AND EXIT 7."* The message style that is currently used is "CONGESTION IN 2 MI". Providing specific information detailing the location of congestion may allow some motorists to divert to an alternate route. Using cross-streets as markers is also helpful: "CONGESTION STARTS AT GLEBE ROAD" would be useful if drivers are likely to know where Glebe Road is located relative to the interchanges immediately preceding and following it.

  Furthermore, when drivers have already encountered a traffic delay, the TMS may want to consider using the message "TRAFFIC CLEARS AT EXIT 5". In *Guidelines on the Selection and Design of Messages for Changeable Message Signs* (U.S.D.O.T. Report No. FHWA-TX-92-1232-10 p.16), Conrad Dudek writes "Never display the word 'CONGESTION' when drivers are engulfed in congestion. Drivers prefer 'TRAFFIC CLEARS.'" The TMS should decide which messages are more effective.

- *Develop a software subroutine or procedure to select the signs that are activated in case of an incident.* This should take the form of a conditional: if there is an accident between exits 7 and 8, then activate signs 20-25.

- *Establish means for automatic storage of equipment failures, incidents, and software parameter values.* This could be accomplished through customized spreadsheets and software subroutines. The current practice is that an operator writes down accident information and then this data is entered into the computer system at the end of the shift. A customized spreadsheet, where the operator could be prompted with a menu to enter the day, time, location, and cause of an accident, could be used to record accidents. In addition, a software subroutine could be used to automatically record and track equipment failures and previously tried software parameter values. Software parameters are listed in the Appendix.

The following two suggestions, although not related to software subroutines, are equal in importance to those listed above:

- *Place the Safety Service Patrol under direct control of the TMS.* Although the Safety Service Patrol is not a function of the TMS, the two rely heavily on one another to remove disabled vehicles from the road. Furthermore, the Safety Service Patrol and the TMS require close coordination during incident response: the Safety Service Patrol not only removes disabled vehicles but also provides additional on-the-scene information to the TMS. The TMS, in turn, assists the incident removal team by providing additional information available from the TMS's cameras. It is logical, therefore, that these two organizations have one command center to direct their activities. Currently, when the Safety Service Patrol is not on duty, the TMS must rely on State Police personnel to handle vehicle removal, who have the potential to be delayed should they have other duties. *In October, 1993, the Safety Service Patrol began operating 24 hours per day thereby eliminating part of this problem.* However, a move to merge the TMS and the Safety Service Patrol should be considered.

- *Instruct VDOT and private contractor construction crews to update the TMS more frequently.* The TMS should be updated when there is a change in construction schedules. Even if a contractor simply starts an hour earlier or later in the day than was previously planned, the TMS should be notified. At stake is the credibility of the TMS, which suffers during that hour if a sign advises motorists of construction yet there is none or vice-versa.

3. The following suggestions are those the authors feel would be *worth considering* if resources become available. They are listed in their order of importance.

   - *Join "Miss Utility".* The TMS's underground communications cable is still being damaged by contractors. Unfortunately VDOT is not a member of Miss Utility (1-800-257-7777) which contractors are instructed to call at least 48 hours before they dig to avoid hitting underground cables, wires, etc.

   - *Request the State Police to have an officer at the TMS during the peak periods.* This would allow police to immediately call a tow truck or other equipment, at least on some occasions, as soon as an incident is spotted on camera rather than having to wait until an officer can arrive. *It is the authors' understanding that this practice will occur sometime in 1994.*

   - *Enhance TMS communications capabilities with relevant parties.* The list of those individuals or entities that should be in contact with the TMS during an incident includes the police of Fairfax, Alexandria, Arlington, and Washington, D.C.; the Virginia State Police and Maryland State Police; and television and radio stations (such as WTOP, Fairfax County News Channel 8, and Metro Traffic Control). For major incidents, this list should also include the Maintenance Division Emergency Operations Center which informs the I-95 corridor coalition (TRANSCOM). Although direct lines to some of these parties exist, direct lines to all should be considered. It may be feasible to connect the TMS to more than one of these entities at a time, thus enabling operators to update all of the relevant players at once. This would be especially useful during the peak hours. According to TMS personnel, one of the new features of the proposed map-info system will allow these parties to see a digitized map that displays congested areas. This map may also include text entered by the TMS describing various traffic conditions. The TMS is currently experimenting with the map-info system.

- *Examine software parameters.* Frederic R. Harris, Inc., compared some software parameters to those of project INFORM and noted differences between the two systems. Both the TMS and INFORM have the same software system, and although the two systems exhibit different characteristics, it might be useful to determine whether any of these software values may be modified in order to improve the system's performance. These parameters are detailed in the Appendix. The TMS, in conjunction with Parsons Brinckerhoff, Inc., examined some of these software parameters and determined that only one might be worth altering: the "maximum allowable vehicle length used." If resources allow, this might be an effort worth studying with the help of a consultant.

- *Install a second loop detector on each ramp that is metered.* Presently, each ramp has only one detector (unlike the INFORM TMS, which has two). With only one detector, long ramp queues (which are unacceptable to nearby residents) tend to form before the queue alarm is activated, which means that TMS operators must visually check each ramp to be sure no long queue has formed. Unfortunately, it appears that the problem of long queue formation cannot be solved by modifying the software. It takes one minute for the detector data to be transmitted to the software and one minute for this software to trigger an alarm, yet a ramp queue can form in less than two minutes. A second detector would make the alarm system more sensitive to queues but would not eliminate the problem of queues forming quicker than the TMS can automatically detect them.

- *Document the TMS's priorities and duties.* Put into a concise format what the TMS operators already know. The TMS has documentation in the form of memos, letters, and a Perkins-Elmer operator's manual but no training manual exists per se. This training manual would enable outside consultants to have the background information necessary to make useful improvements to the TMS hardware and software. The inclusion of the team approach followed by the TMS operators would also be useful. The greatest benefit of this manual would be to provide consultants and other VDOT employees with a knowledge of what the TMS does so that they may better ascertain what the TMS needs. This step would be essential if a contractor were to work with the TMS to significantly upgrade or overhaul the system. However, it is likely not cost-effective for training purposes only.

In addition to the above system and procedural recommendations, one additional policy recommendation is offered:

- *VDOT should set aside funds earmarked for preventative maintenance at the TMS.* As equipment wears out and becomes outdated, the TMS will need funds in order to repair, replace or upgrade it. For example, as loop detectors are destroyed by pavement maintenance projects on I-395, funds will be needed to replace them as soon as they are destroyed. Without these detectors, the TMS will not have accurate data and will be hampered in its efforts to provide accurate traffic information to the public. Moreover, as technology improves and demands placed on the TMS increase, the TMS may need to repair, enhance, or replace its coaxial communications system. A preventative maintenance fund will enable the TMS to respond to these demands and upgrade its systems accordingly.

APPENDIX

Software Parameters

These parameters are available under the *System Tuning Report* in the arrays FILTER (Filter Smoothing Factors), THRSHI (Integer Threshold Values), and THRSHR (Real Threshold Values). The TMS values and the INFORM values are listed for the purpose of comparison. Although both systems use the same software, the systems do not necessarily have the same characteristics. At this time, only the first parameter listed ("maximum allowable vehicle length used") is worth changing. It is suggested that the value be increased to 50 feet, since I-395 may have a large percentage of trucks because of restrictions on I-66. Furthermore, the vehicle length (Index 10 of FILTER SMOOTHING FACTORS) has the same value as that used for INFORM, so one might presume the maximum allowable vehicle length should be the same.

The remaining parameters are listed in the event that a consultant might study them. At this time, however, it is not recommended that their values be changed. However, it appears that project INFORM may need to change their value of "time to end detector off to long eval."

Table 1
COMPARISON OF PARAMETER VALUES BETWEEN TMS AND INFORM

Parameter	INFORM value	TMS value	Units	Index
Maximum allowable vehicle length used	50	17	feet	2^R
CCU hard failure threshold	20	6	1/4 sec	1
CCU temporary failure threshold	10	1	1/4 sec	3
RCU hard failure threshold	50	80	1/4 sec	4
RCU temporary failure threshold	20	10	1/4 sec	6
Passage too long, turn green if demand	3	5	1/4 sec	11
Nominal meter response lag	1	3	1/4 sec	16
Time to end detector off too long eval	24	3	hour	7
Incident acknowledge threshold	15	20	minute	17
Master sign controller hard failure threshold	30	1	20 sec	19
Sign hard failure threshold	3	2	20 sec	21
Ramp controller hard failure threshold	40	100	1/4 sec	22
Trap passage min/lim for on too long	3000	3200	1/60 sec	31

continues

Table 1
COMPARISON OF PARAMETER VALUES BETWEEN TMS AND INFORM (Continued)

Parameter	INFORM value	TMS value	Units	Index
Time to start detector off too long eval	6	2	hour	32
Incident detection magnitude threshold	12	15	%	4^R
Incident detection ratio threshold	0.6	0.5	ratio	5^R
Incident removal ratio threshold	0.5	0.4	ratio	9^R
Congestion continuation threshold	30	20	%	16^R
Congestion clear occupancy threshold	23	17	%	18^R
Option rate trigger occupancy	10	18	%	22^R
Option rate release occupancy	7	15	%	23^R
Excess capacity per lane to go to meter or non meter	400-800	500-600	vph/lane	24^R,25^R
Detector off too long headway ratio	20	30	ratio	29^R
Decoupling reflected capacity addition	50	100	vph/lane	30^R
Current ramp occupancy	0.400	0.900	none	2^F
Historical ramp volume	0.001	0.080	none	3^F
Historical ramp occupancy	0.001	0.080	none	4^F
Historical mainline volume	0.001	0.080	none	8^F
Historical mainline occupancy	0.001	0.080	none	9^F

Notes: An "R" in the "Index" column indicates that the index refers to REAL Threshold Values; an "F" indicates that the index refers to filter smoothing factors, and the lack of a letter indicates that the index refers to Integer threshold values.