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TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study: Operator Response Time Analysis

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Operator Response Time Analysis**

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ABSTRACT

TravInfoTM is an advanced traveler information system for the San Francisco Bay Area that began operation in September 1996 under a public/private partnership seeking to compile, integrate, and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), TravInfoTM's information gathering, processing, and dissemination hub. For two years, until September 1998, it was a Field Operational Test (FOT) sponsored by the Federal Highway Administration. Since the end of the test TravInfoTM has been in a transitional or "as-is" phase continuing its operation without major changes to the TIC relative to the test phase. September 2000 is the tentative date when a new system manager for the TIC is expected to assume its managerial and operational responsibilities. At this time, TravInfoTM moves into a more stable and likely permanent part of the Bay Area's information technology infrastructure.

During the Field Operational Test, TravInfoTM's TIC was evaluated with respect to system reliability, the communications interface, the operator interface, and operator response time. This report documents the analysis of operator response time that is a significant part of the evaluation because TravInfoTM's operations are substantially less automated than originally envisioned and so depends to a significant degree on operator performance.

Focus was placed on incident information generated by the California Highway Patrol's Computer-Aided-Dispatch (CAD) system. Response time is defined as the elapsed time once information is collected from the CAD system until it is disseminated to the public via the Traveler Advisory Telephone System. Response times remained stable during the FOT with an overall average operator response time of approximately 11 minutes though there were significant response time differences among the operators. It is expected that once TravInfoTM enters its more permanent and stable phase with a new system manager, operations will become substantially more automated and this should have a significant impact on reducing operator response times as well as increasing overall operator productivity. Automating operations coupled with the much stricter operator quality control measures that were put in place near the end of the FOT should combine to make operations more like the "timely" undertaking it was intended to be.

Key Words: TravInfoTM, Field Operational Test, evaluation, traveler information center, advanced traveler information systems, operator response time

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EXECUTIVE SUMMARY

TravInfoTM is an advanced traveler information system for the San Francisco Bay Area that began operation in September 1996 under a public/private partnership seeking to compile, integrate, and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), TravInfoTM's information gathering, processing, and dissemination hub. For two years, until September 1998, it was a Field Operational Test (FOT) sponsored by the Federal Highway Administration. Since the end of the test TravInfoTM has been in a transitional or "as-is" phase continuing its operation without major changes to the TIC relative to the test phase. September 2000 is the tentative date when a new system manager for the TIC is expected to assume its managerial and operational responsibilities. At this time, TravInfoTM moves into a more stable and likely permanent part of the Bay Area's information technology infrastructure.

The evaluation of TravInfoTM consisted of three major elements: (1) institutional, (2) technology, and (3) traveler response. The TIC study was part of the technology evaluation and consisted of four primary elements: system reliability, communications interface, operator interface and operator response time analysis. System reliability examined system problems. The communications interface examined TIC data access on the part of both the public and private sectors. Operator interface investigated the human element by considering the role of the operator in the flow of information through the TIC, the operators' tasks and responsibilities and the operators' physical working environment. Response time measured the operations' processing time of incidents between entry into the TIC and dissemination to the public and private sector. TravInfoTM operations were considerably less automated than originally envisioned and more dependent on operator performance and so operator response time took on added significance.

One of TravInfoTM's primary goals has been to provide timely traveler information, but there is no unambiguous and generally accepted meaning of "timely" in this context. The operator's response time is critical to how well the center meets this ambiguous goal. However, with no baseline value for what a "timely" response is, the timeliness of operators' responses could not be comparatively assessed. Factors that could influence operator response times, however, were identified and their influence assessed.

Two one-week analyses approximately six months apart were conducted during the final nine months of the field test. Response times were examined between 5 a.m. and 8 p.m. for each day of these two weeks. Response time was defined as the time between an incident first being posted on the California Highway Patrol's Computer-Aided Dispatch (CAD) system and it being entered into the TravInfoTM phone system and available to the public.

During the FOT, as reflected in the two-wave test, average response times for processing incidents from the Highway Patrol's Computer-Aided Dispatch system and disseminating the information to the public through the Traveler Advisory Telephone System remained stable with an average value of approximately 11 minutes. Approximately 20% of the total number of incoming Computer-Aided Dispatch incidents were entered. Operators' job performance and

level of operator workload were the two primary factors influencing the number of incidents entered into the system and operator response times for those entered incidents. Other factors were also examined to assess their influence on operator response times, such as number and type of incidents (e.g., traffic hazard, accident with major injuries) reported by the California Highway Patrol, time of day, the location (Operator Work Station) where the incident was processed, i.e., the specific geographic workstation, level of operator work experience at the TIC, incident arrival rate, operator work-break periods, weather conditions, and system software and hardware problems (documented by operators). These factors, however, played only a minor role in influencing response times.

Numerous operator work activities also affect operator response times and help provide the fuller context within which response times were assessed. These activities included attempts to verify an incident, disruptions caused by their own and other operators' shift changes, operator call-checking into the phone advisory system for quality control purposes, updating an incident already entered into the system, searching for multiple listings for the same incident or those not delaying traffic flow. However, these activities were difficult to isolate and individually quantify their contribution to operator response times.

It is anticipated that once TravInfoTM enters its more permanent and stable phase with a new system manager, operations will soon become substantially more automated and this should have a significant impact on reducing operator response times as well as increasing overall operator productivity. It is recommended that once these changes are implemented, subsequent operator response time assessments be made. Automating operations coupled with the much stricter operator quality control measures that were put in place near the end of the FOT should combine to make operations more like the "timely" undertaking it was intended to be.

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1. INTRODUCTION

This report documents the Response Time element of the Traveler Information Center (TIC) evaluation as described in the TIC evaluation plan (1). This TIC evaluation element focuses on the time cycle for data acquisition, processing, and dissemination through the TIC. Providing timely information is a primary goal of TravInfo™ (2,3). There is, however, no unambiguous and generally accepted meaning of “timely” in this context.

The System Requirements document (4) produced by the consultant-led (TRW) TIC design and development team states that:

- o Freeway incident data (dynamic data type) would arrive at the TIC from the Traffic Operations System
- Average latency of dynamic data would be no more than one minute, i.e., “the time delay from the time of dynamic information receipt to the time of TravInfo™/TIC output results” into the Landline Data Server (LDS) and the Traveler Advisory Telephone System (TATS).

This, however, does not take into account the time between the incident’s occurrence and the center first being aware of it that would include the time until the incident is first observed, reported to proper authorities, and forwarded onto the TIC. Thus, “timely” does not necessarily mean “instantaneously” and remains somewhat of an ambiguous goal. Also, with no baseline value for what a “timely” response is, the timeliness of operators’ responses could not be comparatively assessed with any reference response time measure. Factors that could influence response times, however, were identified and analyzed to determine their impact on operator response times. Based on these findings, recommendations are made for altering certain factors in order to reduce operator response times.

The California Highway Patrol Computer-Aided Dispatch system is the primary Traveler Information Center data source (5) for entering, processing and disseminating data. Since data from this source needs to be manually entered, it would very likely require longer than one minute and could create a potentially serious bottleneck in Traveler Information Center information flow. Thus, investigating operator response time, in particular since it depends to a great extent on operator work performance, is an important component of the overall TIC evaluation. The remainder of this section explains the specific objectives for this part of the evaluation and provides additional background material before discussing the study design, methodology, performance measures, and findings.

1.1 Background and Objectives

The objective of the work reported in this document is to assess TIC performance over the course of the TravInfo™ Field Operational Test (FOT) relative to response time, that is, the amount of elapsed time once data enters the TIC to be processed and disseminated. Information is disseminated to the public via the Traveler Advisory Telephone System and to the private sector via the Landline Data Server. Data transfer from the TIC to the LDS is instantaneous, whereas transfer from the TIC to TATS is not, so focus in this analysis was placed on the TIC to TATS

connection. The operator plays a significant role in all phases of data manipulation at the TIC (5,6), resulting in time being a relevant factor to overall TIC performance. Studying response time will also allow evaluators to make recommendations for improvements in overall TIC performance where needed.

2. STUDY DESIGN

The response time evaluation was conducted by analyzing data from a specially designed and constructed database consisting of all relevant response time data. As described in (1), focus was placed on incidents. The schedule outlined in (1) called for a response time analysis to be conducted every six months with approximately four waves during the FOT. There were issues at the TIC that impacted the collection of relevant response time data and these issues were not completely resolved until fall 1997 when the two-year FOT was half complete¹. With one year remaining until the conclusion of the FOT, it was decided that response time would be assessed twice, i.e., in two waves.² Each wave would consist of examining one week's worth of data³ to analyze this aspect of TIC operational effectiveness. Each wave's results would provide a description of the timeliness and responsiveness of TIC operations. Comparing and contrasting each wave's results would also document changes over time. This document reports the findings of both waves.

Two one-week, i.e., the workweek (Monday through Friday), analyses approximately six months apart were conducted during the final nine months of the field test⁴. The time periods for Wave 1 and 2 were, respectively, the weeks of January 12 – 16 and June 22 – 26, 1998. Response times were examined between 5 a.m. and 8 p.m. for each day of these two weeks. Response time was defined as the time between an incident first being posted on the California Highway Patrol's Computer-Aided Dispatch system and it being entered into TATS and available to the public.

There are some notable intermediate times between these two times, such as the time between an incident being posted and an operator being aware of its posting and the gap between an operator's initial awareness of a posting and its verification by the California Highway Patrol. The time between the first appearance of an incident record in the California Highway Patrol's Computer-Aided Dispatch system and operator awareness of it depends mainly on the operator's workload and attentiveness. Operators are instructed to confirm an incident before entering it into the database and they make attempts to do this. However, according to operators, actual

¹ Issues associated with supporting the response time study that needed resolution prior to its start included: 1. PATH acceptance of outstanding evaluation-related TIC Acceptance Testing procedures, 2. Implementation of a change in data entry procedures for incidents, 3. Resolution of a particular TIC workstation problem (cross pollination among workstations).

² Performing additional waves was considered but could not be accommodated due to evaluation resource constraints in fulfilling other TIC evaluation responsibilities.

³ Originally each wave was to consist of a two-week period. Due to the enormous amount of data that had to be collected, reduced, and analyzed, even for one week, coupled with staffing limitations, each wave was reduced in length to one week.

⁴ No weekend data was collected or analyzed. Emphasis was placed on the most heavily traveled days of the week and the most heavily traveled hours for such days.

verification does not always occur before an entry is made in the interest of remaining timely. Operators use several means to confirm an incident, including an on-site California Highway Patrol officer report, an airborne record, a web-service report, multiple Computer-Aided Dispatch entries for the same incident, and operators' experience about incidents occurring at certain locations during certain time periods.

During the time between the first appearance of an incident record in the California Highway Patrol's Computer-Aided Dispatch system and incident verification (if it actually occurs), operators are making incident verification attempts for that particular incident, as well as performing other activities related to other incidents and other Traveler Information Center operational matters. Because operators take an active role in trying to confirm an incident before entering it into the TIC database, operator performance is a factor and including this time in the definition of operator response time helps document how close to "timely" the information is. During this time, incident information is available for processing and dissemination. The time between incident verification (again, if it occurs) and entering the processed incident into the Traveler Information Center database is related more to the specific incident under examination.

The following factors could potentially influence operator response times:

- Number of incidents to be processed; the rate at which incidents arrive
- Type of incident (e.g., traffic hazard, accident with major injuries)
- Time of day
- Location where the incident is processed (i.e., the specific geographic workstation)
- Length of the operator's experience working at the Traveler Information Center
- Time and nature of the California Highway Patrol's Computer-Aided Dispatch system problems (documented by operators)
- Time and nature of the Traveler Information Center's system problems (documented by operators)
- Operators' work-break periods
- Weather conditions.

Approximately 90% of TIC data processed by the three geographic workstations originates with the CHP CAD. As documented in (5), all operators use the CHP CAD as a source of information for approximately 75% of their time. During the FOT, operators ranked the CAD as the number one TIC data source and stated it was "very useful," if not critical, to the functioning of the TIC. Moreover, other incident-related data sources were incomplete and could not be used in constructing the response time database. For all these reasons, only CHP CAD-generated incident data was used in the response time analysis.

The response time database was constructed by compiling and organizing data from the following five sources. Multiple sources were required to obtain all necessary data and to be able to match data from multiple sources associated with the same incident.

- CHP CAD Incident Retrieval Report
- Operator Audit File (OAF)

- Operator Activity Report (OAR)
- TATS Tracker Sheet
- Operator Activity Check Sheet

Relevant data contained within each of these sources are listed below:

CHP CAD Incident Retrieval Report (hard copy⁵ record of each incident entered into the CAD system):

- CAD incident identification number
- Incident date
- Incident time (when incident information was entered *into the CAD system*)⁶
- Incident location
- Incident type (as defined by CHP Aural Brevity Codes, e.g., 1125 (traffic hazard), 1180 (accident—major injury))

Operator Audit File (electronic record of each item entered into the TIC's database):

- Entry date for TIC item
- Entry time for TIC item
- Operator workstation for TIC item
- TIC item identification number

TATS Tracker Sheet (hard copy record of each TIC item entered into TATS):

- Entry date for TIC item
- Entry time into TATS
- Operator workstation
- Operator
- CHP CAD incident identification number for incidents
- TIC item identification number
- TATS mailbox number

Operator Activity Report (electronic record of each TIC item entered into TATS):

- Entry date of TIC item
- Entry time of TIC item
- TIC item identification number
- Operator identification number
- TATS mailbox number

⁵ The CHP was able to provide electronic files for Wave 1 and a hard copy record for Wave 2.

⁶ For Wave 1, CHP CAD incident times were provided with up-to-the-second accuracy, but only up-to-the-minute accuracy for Wave 2 incident times. In order to continue entering times into the master response time database in hour:minute:second format to be consistent with other database entries to calculate response times and with Wave 1, CHP CAD times for Wave 2 records were entered as having been time stamped at the halfway point in the minute during which they occurred, e.g., a record with a CHP CAD time stamp of “10:08 A.M.” was entered into the database as “10:08:30 A.M.”. This procedure, done consistently for all Wave 2 records introduces up to a 30 second margin of error in the calculation of response times.

Operator Activity Check Sheet:

- Operator identification number
- Operator

The entry time into TATS for a TIC item recorded on the TATS Tracker Sheet by each operator is not always a reliable source of actual TATS entry time. The operators do not use the same timepiece nor are there any assurances that the timepiece each does use is accurate. Moreover, some operators do not always enter the time when they actually make the entry, but enter it later once they have realized they omitted this information. An even less accurate estimate of entry time is then recorded. Because of these problems, the Operator Activity Report was used to obtain an accurate TATS entry time for each CAD-generated TIC item.

After obtaining and compiling this data⁷, the constructed master response time database consisted of 708 and 634⁸ records for the two waves, respectively with the following fields:

- CAD incident identification number
- Incident date
- Incident entry time into CAD (CAD Time)
- CAD incident type code
- Location
- Incident TIC-identification number
- Operator workstation
- Incident entry time into TIC (TIC Time)
- Incident entry time into TATS (TATS Time)

Before analyzing the data, changes were made to data in both the TIC time and TATS time fields to insure that all three times (CAD, TIC, and TATS) were synchronized with each other. The CAD system clock is synchronized daily with an accurate time measure so no changes were necessary for CAD system time.

3. METHODOLOGY AND PERFORMANCE MEASURES

The response time analysis covers the time from when an incident is initially input into the CAD system until it is input into TATS and available to the public. The two components of this total response time, CAD to TIC time and TIC to TATS time, were performed separately. The method used to investigate both components consisted of the writing and running of queries in the response time database relative to different criteria.

⁷ Data from the Operator Activity Check Sheet was used in conjunction with the Operator Activity Report to help associate different data with each other and was not specifically entered into the master response time database.

⁸ For Wave 2, operators entered 738 records into the TIC database. Of these records, 104 correspond to missing records from the CHP CAD log and so were not included in the master response time database as response times for them could not be calculated.

For the CAD to TIC component, for each query run, i.e., for each specific criterion, the response time distribution was also calculated. The performance measures used were 1. Average response time, 2. Standard deviation of response time, 3. Number of incidents with a particular response time range, 4. Number of incidents processed per hour and 5. Ratio of the number of TIC items processed to the number of CAD items (adjusted for repeat records and records not considered by operators by incident type). Criteria include the following:

- Day of week
 - Time of day (individual hours, A.M./P.M. shifts, A.M./P.M. peak periods)
- Type of incident
 - Operator geographic workstation

In addition to these measures of performance, statistical hypothesis testing was performed to assess the significance of operator response time variability (See Section 4.1.2).

For the TIC to TATS component, the performance measures used were 1. Average response time and 2. Standard deviation of response time. Criteria include the following:

- Day of week
- Time of day (A.M./P.M. shifts)
- Operator geographic workstation

4. STUDY FINDINGS

This section provides the major findings of the response time analysis with separate sections for the CAD to TIC and the TIC to TATS components. The main reasons for dividing the analysis into these two parts are 1. Differences in the set of records for which there were complete data, 2. Substantially different response time ranges between these two components, and 3. Different sets of explanatory variables to consider in order to understand the magnitude and variation in response times.

4.1 CAD to TIC

The response time analysis covers the time from when an incident is initially input onto the CAD by a CHP dispatcher until it is input into TATS and available to the public. Incident information appears on a CAD terminal at the TIC as soon as it is entered by a CHP dispatcher. As TIC operators may be performing other tasks, especially during busy times, and would not necessarily stare at the CAD screen waiting for the next incident to appear, the CAD to TIC time for an incident includes the time until it is observed by an operator. While operators do work to confirm the validity of an incident before entering it on the TIC, incidents are definitely entered into the TIC without official CHP confirmation. This is based on operator interviews and observations by the evaluators. Means of incident confirmation include Metro Networks Airborne and Instatrack (a Web-based tool), operators' experiential knowledge about incidents at

particular locations and during particular times, Closed Circuit Television, and confirmation by a CHP officer at the site of the incident.

The objective in performing the CAD to TIC response time analysis was to explain the magnitude and variability in these response times. This is accomplished by considering the explanatory variables individually (See Section 4.1.1) and simultaneously (See Section 4.1.2)

4.1.1 Descriptive and Aggregate Statistics

This section of the report discusses the response time study findings from a descriptive and aggregate statistical perspective. The primary objective is to examine operator response times and explain their magnitude and variability. As explained in the study design section, data was collected for two one-week periods from 5 A.M. to 8 P.M on Monday January 12 through Friday January 16, 1998 (Wave 1), and on Monday June 22 through Friday June 26, 1998 (Wave 2). This data consisted exclusively of incidents arriving on the CHP CAD terminal that were processed by operators then entered into the TIC database. There are four on-duty TIC operators from 5 A.M. to 9 P.M. Three of these operators handle mostly incident data and the remaining operator processes roadwork and slowdown information, i.e. information pertaining to commute hour slowdowns on freeways. This section focuses on the response time of the operators located at the three workstations handling incident data (operators at the TIC rotate according to a morning and afternoon shift. Hence, what is measured in these study findings is the response time of different operators located at the three workstations handling incident data) from the CHP CAD. For purposes of the analysis below, these three workstations will be referred to as workstations 1, 2 and 3.

4.1.1.1 Operator Work Efficiency

During Waves 1 and 2, a total of 10,619 and 10,967 records were entered onto the CAD by CHP dispatchers, respectively. Operators at each of the three geographic workstations examined these records to determine which ones would subsequently be entered into the TIC. An important measure of operator performance is their work efficiency, i.e., the ratio of the number of records entered into the TIC out of the total number of records coming into the CAD. It would be incorrect to divide the number of TIC records for each wave by the number of CAD records for each wave (10,619 or 10,967) for this time period to estimate work efficiency. There are incidents that are not considered because they do not impact traffic and there are incidents for which there are multiple records. Both these incident types should first be removed from the CAD record population prior to the calculation of work efficiency. The former group consists of the following CHP CAD Codes' and total 2,801 and 3,753¹⁰ out of the 10,619 and 10,967

⁹ These codes are referred to as CHP Aural Brevity Codes with which CHP staff communicates for brevity.

¹⁰ The CHP CAD log contained missing records for Tuesday (June 23) and Thursday (June 25). This total (3,753) represents an exact calculation for records that do not impact traffic for three of the five days of Wave 2 (no missing records) plus an estimate of records that do not impact traffic during the two days with missing records.

records respectively for Waves 1 and 2: 1126, 1125C, and 3A¹¹ with 7,812 and 7,213 records remaining.

An estimate for the number of records in the latter group, i.e., records that are input into the CAD multiple times, was determined by the following methodology. As it was infeasible to individually examine each of the 7,812 and 7,213 records, i.e., the record populations for Wave 1 and Wave 2, respectively, to determine which ones were previously recorded into the CAD, a random sample of 100 records from each population was selected. Each member of the two samples was subsequently examined to determine whether or not it had been previously recorded in the population. After this examination, each sample of 100 consisted of the following two components: those records that had not been previously recorded and those that had been. For each record in each sample, all population records with a CAD timestamp within fifteen minutes prior to the sample record CAD timestamp were examined. It was assumed that if a record had been previously recorded, fifteen minutes would be an acceptably sufficient time period with which to capture that repeat (at least one of them, for multiple repeats). The percentages of sample records previously recorded for Wave 1 and 2 were 32% and 34% respectively.

The issue of duplicates, triplicates, quadruplicates, and so on arises since a record may be replicated a multiple number of times. The sample records were examined only to determine if they were repeats of previous records and did not specifically count the number of such replications. Varying number of replications is, nevertheless, accounted for in the following way: There is only one replication for each duplicate, two replications for each triplicate, three replications for each quadruplicate, and so on. Thus, the probability of finding a replication for a duplicate is less than or equal to the probability of finding a replication for a triplicate, which are less than or equal to the chances of finding a replication for a quadruplicate, etc. Thus, the different kinds of replications are represented in the percentage breakdown of records with/without replications¹².

Another issue is determining how representative of the actual record population is the random sample of 100. The objective in choosing a random sample of a particular size, N, is to have N be large enough so that the following statistical statement is justifiably valid:

With 95% confidence, the percentage of sample records that were previously recorded is within +/- X% of the actual percentage of population records that were previously recorded. That is, there is only a 5% chance that the actual percentage of the population that had been previously recorded is beyond the range of +/- X% from the sample percentage.

¹¹ CAD Code 1126 = Stalled vehicle not blocking a lane, 1125C = Stalled vehicle in the center divide, 3A = American Automobile Association (AAA) has been called to tow the vehicle.

¹² For example, consider the following two populations: One population consisting of records with duplicates (one replication) and records with no replications. The second population consists of records with triplicates (two replications) only and records with no replications. Examine a random sample from each population. The first population would have a percentage of records that had been previously recorded less than or equal to the analogous percentage of records for the second population.

The smaller one desires “X” to be, the larger the sample size must be. With a random sample of size 100, X takes on the values of 9.4 and 9.5 for Waves 1 and 2, respectively¹³. Thus, with 95% confidence, the actual percentage of Wave 1 population records that were replicated is 32% +/- 9.4%, i.e., an interval ranging from 22.6% to 41.2%. The “9.4%” is larger than usually accepted in practice. It is accepted and used here because operator work efficiency is the final measure to be estimated and efficiency is fairly insensitive to values of X and hence, examining a larger random sample was unnecessary. Operator work efficiency ranges from 11.7% to 15.5% with a value of 13.3% that corresponds to the empirical result of 34% replicated records from the random sample of 100¹⁴. Being conservative and erring on the side of the larger value for work efficiency, the upper limit of 15.5% efficiency is henceforth used. This corresponds to 4,567 records¹⁵. For Wave 2, the corresponding 95% confidence interval ranges between 24.5% and 43.5% corresponding to a range of operator work efficiency between 13.6% and 18.1%¹⁶. Again being conservative and erring on the side of the larger value for work efficiency yields the upper limit of 18.1% efficiency corresponding to 4,064 records.

The estimated number of distinct records coming from the CAD on which operators focus their attention, i.e., the 4,567 items for Wave 1 and 4,064 records for Wave 2, provide an approximate upper bound on the volume of records that could be processed. Even with significant increased work efficiency, it is not likely that this volume of processed items could ever be achieved without additional operators all else being equal. Operators state that it takes approximately 3 to 4 minutes to process each item arriving from the CAD¹⁷ (1). This rate translates into a total ranging from approximately 3,375 to 4,500 records that could be processed by 3 operators (3 workstations) over 15 hours (5 A.M. TO 8 P.M.) over 5 days (Monday through Friday). This means that currently from 15.7% (708/4,500) to 21.0% (708/3,375) of the total number of CAD records *that operators say could be processed* are being processed for Wave 1 and between 16.4% (738/4,500) and 21.9% (738/3,375) for Wave 2. Again, even with significant increased work efficiency, it is not likely that this volume of processed items could ever be achieved without additional operators.

Thus, during Wave 1 and Wave 2, 708 incidents out of 4,567 CAD items and 738 out of 4,064 CAD items, respectively were processed or entered into the TIC database at workstations 1, 2 and 3. Since these incidents were fairly evenly distributed by day-of-week and there were no statistically significant differences in response times by day of week, the response time data was initially aggregated by hour of the day and/or operator workstation for the whole week. More detailed analysis will be presented later in this section.

¹³ This is based on the values for the sample size, standard deviation, and the standard error.

¹⁴ $11.7\% = 708 / (7,812 - (22.6\% * 7,812))$; $15.5\% = 708 / (7,812 - (41.4\% * 7,812))$; $13.3\% = 708 / (7,812 - (32\% * 7,812))$.

¹⁵ The complete discussion of this methodology may be found in (7). Using this methodology depends on the probability of a sample member having a replication being independent of the probability of another sample member having a replication. While this is not guaranteed, it is, nevertheless, fairly likely to be true in this case.

¹⁶ This calculation is based on the number of operator-entered records into the TIC database, i.e., 738, not the reduced number of 634 after missing records have been accounted for: $13.6\% = 738 / (7,213 - (24.5\% * 7,213))$; $18.1\% = 738 / (7,213 - (43.5\% * 7,213))$. Otherwise, operator efficiency would be incorrectly reduced.

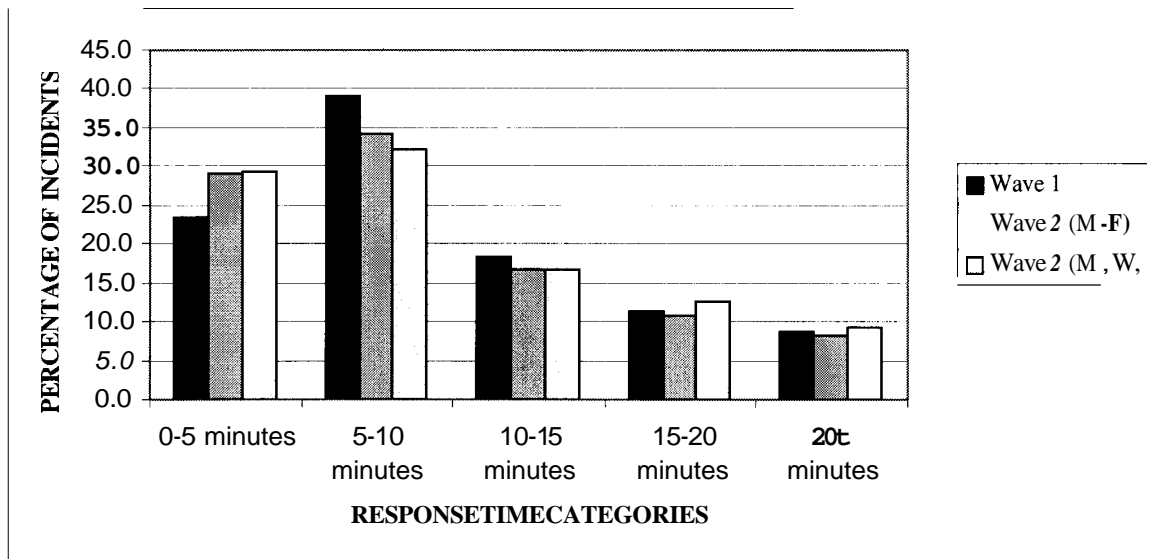
¹⁷ This is the process starting with incident record retrieval from the CAD to inputting the incident message onto TATS.

4.1.1.2 Aggregate Measures by Operator Shift, Time of Day, and Operator Work Station

If we look at Monday through Friday for Wave 2 to reflect the actual number of incidents entered into the TIC, we won't be able to calculate response times for each of the five workdays because we don't have all data for CAD times for Tuesday and Thursday. Alternatively, if we use Monday through Friday for the modified data set, i.e., removing records corresponding to the missing CAD data, then we can estimate response times for all the data in this modified data set but we have now excluded incidents for which operators entered data into the TIC, so operator statistics would be biased downward. For these reasons, we have concentrated on Monday, Wednesday, and Friday for the Wave 2 analysis; however, we occasionally display Monday through Friday response time measures (on the modified data set after removal of records corresponding to missing CAD data) to show performance measure stability with the abbreviated Wave 2 week for Monday, Wednesday, and Friday.

Figure 1 displays an overview of the distribution of response times for Waves 1 and 2 with two distributions (1. Monday through Friday and 2. Monday, Wednesday, Friday) depicted for Wave 2 to account for the missing data in the CHP CAD data on Tuesday and Thursday during the Wave 2 week. While there are differences between Waves 1 and 2, a single pattern emerges. For each Wave, approximately 63% of the incidents arriving through the CAD and entered into the TIC have a response time of less than or equal to ten minutes. However, approximately 20% of these incidents have a response time of fifteen minutes or more. The overall average and standard deviation for CAD to TIC response times are 10.1 minutes and 7.4 minutes for Wave 1, 10.1 minutes and 8.5 minutes for Wave 2 (Monday through Friday), and 10.3 minutes and 9.2 minutes for Wave 2 (Monday, Wednesday, Friday) respectively.

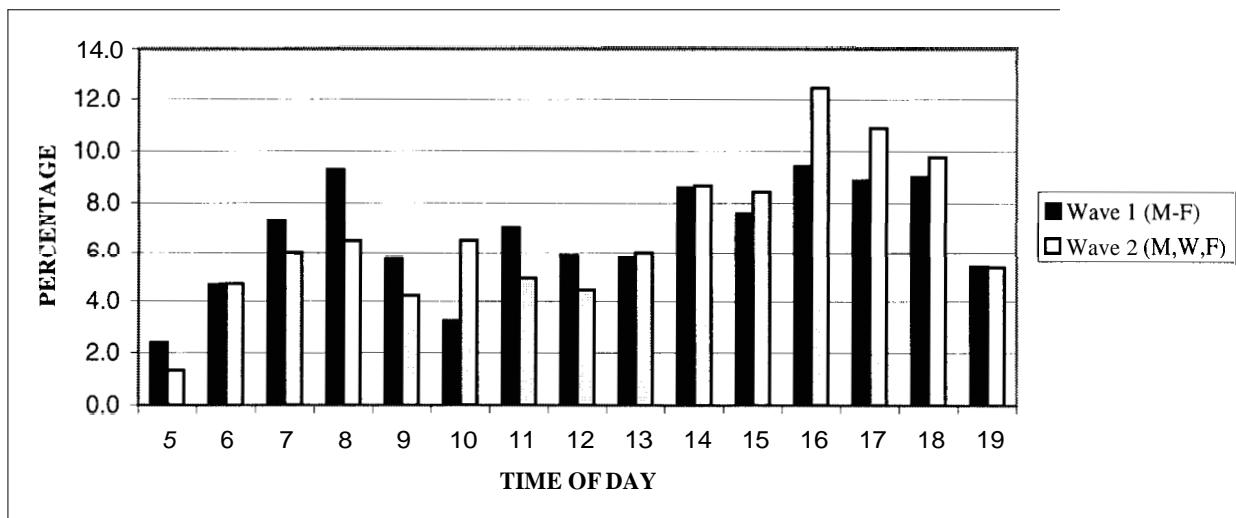
Figure 1: Response Time Distribution for TIC Processed Incidents



The analysis now focuses on response time data by hour-of-day for the three workstations aggregated. Figure 2 displays the percentage breakdown of processed incidents by hour-of-day. Again, while differences exist for these results between Waves 1 and 2 (Monday, Wednesday, Friday) generally the same patterns emerge. As expected, peaks occur mostly during morning and afternoon commute hours. The morning peak occurs from 8 to 9 A.M. wherein approximately 9% of overall incidents were processed during Wave 1. However, approximately 6.4% of overall incidents were processed for Wave 2 (Monday, Wednesday, and Friday). During the afternoon, the pattern corresponds more to a plateau with a marked increase from 1-2 P.M. and a pronounced fall from 7 to 8 P.M.

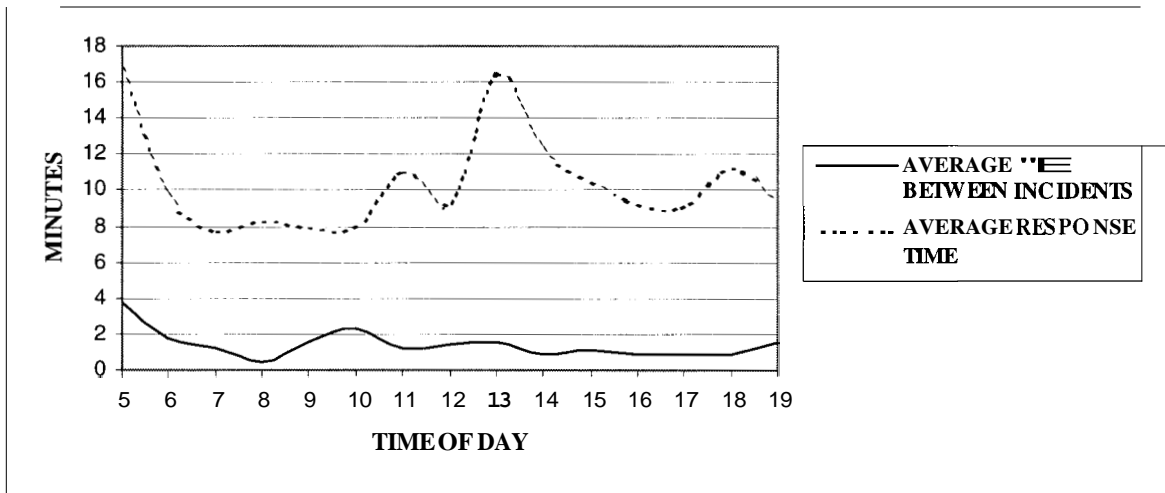
Figure 3 shows graphs of the average response time per incident and the average time between the processing of incidents by hour of day for *Wave 1* (Wave 2 data shows similar behavior and is not explicitly depicted here). Points on the graph with the lowest average time between the processing of incidents correspond to peaks in the number of incidents being processed. The trends in Figure 3 show a very unexpected relationship. One would expect an inverse relationship between the average response time per incident and the average time between the processing of incidents. Indeed, as the number of incidents increases leading to a lower average time between the processing of incidents, in turn, the response time to incidents should increase as the operators are becoming more burdened with work. Instead, the trends in Figure 3 show either mostly a parallel relationship or no discernible relationship at all. During the morning hours from 5 to 9 A.M., the number of incidents processed close to quadruples in response to the morning commute, while at the same time the average response time to incidents is halved from 16 to 8 minutes. From 10-11 A.M., the number of incidents processed is three times lower than at the 8-9 A.M. peak, yet the average response time, instead of declining, remains essentially unchanged at about 8 minutes per incident. Between 11 A.M. and 2 P.M., the number of

Figure 2: Time of Day Distribution for TIC Processed Incidents



incidents per hour remains essentially stable at between 6% and 7% of overall incidents (between 43 and 50 incidents), yet the average response time per hour for this three-hour period goes successively from 11 to 9 to 17 minutes. From 1 to 2 P.M., there is a 50% increase in the number of incidents processed (from approximately 43 to 64 incidents) and the number of incidents remains close to that level until 7 P.M., yet response time continuously decreases from 17 minutes from 1-2 P.M. to a low point of 9 minutes for the 5-6 P.M. hour.

Figure 3: Response Time vs. Incident Arrivals for Wave 1



There is thus no discernible relationship between the number of incidents processed and the average response time to incidents. In fact, the response time pattern that emerges from Figure 3 is the following: response time is generally at its greatest before and after commute time peaks and we surmise this is due mostly to a lack of diligence by some operators. These operators become gradually more diligent and responsive to incidents as the morning and afternoon commute peaks approach as is evidenced by the rapid decrease in response times between 5 A.M. and 8 A.M. (despite a rapid increase in the number of incidents) and between 1 P.M. and 5 P.M. (when the number of incidents remains stable). After the commute peaks, response times increase as these operators become less diligent as is clear from the crests in response time from 11 A.M. to noon and from 6 to 7 P.M.

Thus, the response time to incidents depends only little on the number of incidents coming into the TIC (i.e. how burdened the operators are) but mostly on the quality of work produced by those specific operators. For Wave 1, Table 1 displays the number of incidents processed at the TIC, the average response times and the number and arrival rate of items coming into the CAD for the morning and afternoon shifts¹⁸. When analyzing the numbers displayed in Table 1 no clear relationship emerges between the number and arrival rate of CAD items, the number of

¹⁸ The noon hour was omitted from this table resulting in an equal number of hours per time period. Shift changes occur during the 5am and 1pm hours.

items entered into the TIC and the average response times. For example, during the morning shift, the best average response time was logged on Monday at 7.8 minutes per incident yet Monday was the busiest day of the week with 900 items coming into the CAD and 76 items processed into the TIC. With regard to the CAD incident arrival rate, the numbers for the afternoon shift similarly speak of a lack of correlation: while the CAD item arrival rate is generally stable at between 19 and 23 seconds, the average response time varies between 9.7 and 12.8 minutes. The numbers from the Wednesday afternoon shift represent another counter-intuitive case: this was the second *least* busy afternoon in terms of items coming into the CAD yet represented the most *busy* afternoon in terms of items entered into the TIC and the second-best response time for the afternoon shift. While it is clear that the number of items coming into the CAD effects the number of TIC items processed and response times, the variability in these two numbers cannot be ascribed to the volume of CAD items alone. Table 2 displays the corresponding information for Wave 2 (Monday, Wednesday, Friday).

Table 1: Wave 1 Aggregate Statistics For Each Shift per Day-of-Week

Time Period		M	Tu	W	Th	F
5 A.M.-Noon	Original number of CAD items	900	672	708	785	769
	Average arrival rate (seconds)	28	37	36	32	33
	Adjusted number of CAD items ¹⁹	382	285	298	339	317
	Number of TIC items processed	76	46	65	48	43
	Work efficiency ²⁰	19.9%	16.2%	21.8%	14.2%	13.6%
	Average response time (minutes)	7.8	9.2	9.3	9.9	9.6
	Standard deviation of response time	3.9	3.8	6.3	7.4	8.8
1P.M.-8 P.M.	Original number of CAD items	1187	1094	1127	1287	1360
	Average arrival rate (seconds)	21	23	22	20	19
	Adjusted number of CAD items	497	469	503	557	592
	Number of TIC items processed	66	61	97	84	80
	Work efficiency	13.3%	14.1%	19.3%	15.1%	13.5%
	Average response time (minutes)	12.8	9.7	10.6	11.3	10.6
	Standard deviation of response time	9.3	7.4	6.6	6.2	7.4

¹⁹ For each day and time period, the original number of **CAD** items was reduced to factor out incidents not considered by operators and repeated records (See discussion given in earlier part of this section of the report).

²⁰ This is defined as the ratio of the number of TIC items processed to the adjusted number of **CAD** items.

**Table 2: Wave 2 (Monday, Wednesday, Friday)
Aggregate Statistics For Each Shift**

Time Period		M	W	F
5 A.M.-Noon	Original number of CAD items	729	743	823
	Average arrival rate (seconds)	35	34	31
	Adjusted number of CAD items ²¹	267	286	306
	Number of TIC items processed	52	60	35
	Work efficiency ²²	19.5%	21.0%	11.4%
	Average response time (minutes)	5.8	7.2	5.7
	Standard deviation of response time	4.3	6.2	4.2
	1P.M.-8 P.M.	Original number of CAD items	1387	1215
Average arrival rate (seconds)		18	21	18
Adjusted number of CAD items		527	451	507
Number of TIC items processed		102	69	92
Work efficiency		19.4%	15.3%	18.1%
Average response time (minutes)		12.9	13.1	11.6
Standard deviation of response time		8.3	7.7	11.0

In fact, when observing incident processing rates operator by operator, it becomes clear that the TIC incident processing and response time variability are due to differences in operator productivity. Tables 3, 4a and 4b display for Wave 1 the incident processing and response time rates for each operator in the morning and afternoon shifts. Two things are clear from these tables for Wave 1 (Comparable results for Wave 2 are shown in Tables 5, 6a and 6b): 1. Substantial differences in operator productivity, as measured both by the average response time and by the average number of items created per hour, are evident and 2. The absolute numbers of items processed into the TIC appear low.

²¹ For each day and time period, the original number of CAD items was reduced to factor out incidents not considered by operators and repeated records (See discussion given in earlier part of this section of the report).

²² This is defined as the ratio of the number of TIC items processed to the adjusted number of CAD items.

Table 3: Wave 1 Response Times and Average Item Processing Rates of Operators

Crew	Operator	Response Time Range (minutes)	Average Response Times (min.)	Items Created Range	Average # of Items Created Per Hour	Average # of Items Created Per Hour During Peak Commute Times
A.M.	A1	6.3 – 7.8	7.3	6 – 22	2	2.7
	A2	5.8 – 12.5	6.9	10 – 31	2.8	3.0
	A3	8.9 – 10.5	9.6	18 – 25	3.3	4.4
	A4	10.4 – 15.9	13.0	15 – 21	12.5	3.2
P.M.	P1	11.0 – 15.2	13.4	19 – 22	3	3.0
	P2	12.4 – 20.4	16.2	15 – 24	3	2.7
	P3	11.2 – 12.5	12.0	18 – 44	14.4	6.2
	P4	7.5 – 7.6	6.9	31 – 40	14.6	4.9

**Table 4a: Wave 1 Response Times and Items Processed by Morning Shift Operators
5A.M.-12 Noon**

		M	T	W	Th.	F
OWS ²³ 1	Operator	A1	A3	A4	A2	A1
	Average response time (minutes)	7.2	8.9	12.9	5.8	6.3
	Number of items created in TIC	20	24	21	11	8
OWS 2	Operator	A2	A1	A3	A4	A2
	Average response time (minutes)	6.0	7.0	9.2	15.9	12.5
	Number of items created in TIC	31	6	18	15	10
OWS 3	Operator	A3	A4	A2	A1	A3
	Average response time (minutes)	10.5	10.4	6.3	7.8	9.5
	Number of items created in TIC	25	16	26	22	25

²³ OWS = Operator Workstation

**Table 4b: Wave 1 Response Times and Items Processed by Afternoon Shift Operators
1 P.M.-8 P.M.**

		M	T	W	Th.	F
OWS 1	Operator	P2	R1 ²⁴	P1	P3	P2
	Average response time (minutes)	18.9	4.7	15.2	12.5	16.1
	Number of items created in TIC	23	25	22	44	24
OWS 2	Operator	P3	P2	P4	P1	P3
	Average response time (minutes)	12.5	12.4	7.5	11.0	11.8
	Number of items created in TIC	18	15	40	19	25
OWS 3	Operator	P4	P1	P3	R2 ²⁵	P4
	Average response time (minutes)	7.6	13.8	11.2	8.9	5.5
	Number of items created in TIC	25	21	35	21	31

**Table 5: Wave 2 (Monday, Wednesday, Friday)
Response Times and Average Item Processing Rates of Operators**

Crew	Operator	Response Time Range (minutes)	Average Response Times (min.)	Items Created Range	Average # of Items Created Per Hour	Average # of Items Created Per Hour During Peak Commute Times
A.M.	A1	4.7 – 5.3	5.0	22 – 24	3.3	4.7
	A2	7.5 – 9.0	8.2	11 – 23	2.4	2.9
	A3	4.2 – 7.0	4.7	2 – 16	1.4	1.0
P.M.	P1	12.7 – 12.9	12.8	49	7.0	8.7
	P2	12.8 – 12.9	12.9	26 – 29	3.9	5.0
	P3	13.1 – 15.7	14.2	17 – 24	2.9	3.8
	P4	7.9	7.9	23	3.3	2.7
	P5	11.6 – 12.8	12.1	20 – 26	3.3	4.7

²⁴ Replacement operator 1.

²⁵ Replacement operator 2.

**Table 6a: Wave 2 (Monday, Wednesday, Friday)
Response Times and Items Processed by Morning Shift Operators, 5A.M.-12 Noon**

		M	W	F
OWS ²⁶ 1	Operator	A1	R3 ²⁷	A1
	Average response time (minutes)	5.3	7.2	4.7
	Number of items created in TIC	24	21	22
OWS 2	Operator	A2	A3	A2
	Average response time (minutes)	7.5	4.7	7.7
	Number of items created in TIC	17	16	11
OWS 3	Operator	A3	A2	A3
	Average response time (minutes)	4.2	9.0	7.0
	Number of items created in TIC	11	23	2

**Table 6b: Wave 2 (Monday, Wednesday, Friday)
Response Times and Items Processed by Afternoon Shift Operators, 1 P.M.-8 P.M.**

		M	W	F
OWS 1	Onerator	P1	P2	P1
	Average response time (minutes)	12.7	12.8	12.9
	Number of items created in TIC	49	26	49
OWS 2	Operator	P2	P3	P4
	Average response time (minutes)	12.9	15.7	7.9
	Number of items created in TIC	29	17	23
OWS 3	Onerator	P3	P5	P5
	Average response time (minutes)	13.1	11.6	12.8
	Number of items created in TIC	24	26	20

For Wave 1, the two most productive morning operators, in terms of average response time and items created, are **A2** and **A3**, although **A2** displays less consistency. Operator **A1** has the best average response time for the morning crew. For the afternoon crew, the most productive operators are **P3** and **P4**. These operators handle approximately 95% and 55% more incidents, respectively, than **P1** and **P2** (62 records were processed by **P1** and by **P2**) yet still manage to have lower response times. The comparison between **P4** and **P2** is striking: **P4** handles approximately 55% more incidents than **P2** yet has an average response time that is only 43% of **P2**'s average response time. These differences in operator productivity are the main explanatory variable for variations in average response times and the number of items processed into the TIC. Indeed, when looking at the best performances for the morning crew that occur on Monday and Wednesday, these are in large part due to both **A2** and **A3** being on staff on those days. For the

²⁶ OWS = Operator Workstation

²⁷ Replacement operator 3.

afternoon shift, the influence of productive operators is even more noticeable. The best days for the afternoon shift occurred on Wednesday and Friday with a high number of items handled and low response times relative to the other days. The performance for those days was mostly due to the presence of operators P3 and P4. Thursday afternoon had the second highest number of items input into the TIC but over 50% of those items were processed by one operator: P3.

Another factor, linked to operator productivity that is disturbing is how few items operators actually process and enter into the TIC, generally between 13.3% and 21.8% of CAD items (Table 1). A majority of the operators (5/8) processed approximately three items per hour during peak commute times (6 A.M. to 9 A.M. and 4 P.M. to 7 P.M.). Considering item-processing rates on an hourly basis, the week as a whole for the three operator workstations, from 5 A.M. to 8 P.M., contains **225** one-hour segments. For 10.7% of these segments, or of the overall TIC worktime, 0 items were processed and for another 14.7% only one item per hour was processed. The aforementioned numbers are particularly low if one considers the following facts: 1. The operators themselves have stated during interviews that it takes them approximately two to three minutes to process an item into the TIC and an additional minute for input into the Traveler Advisory Telephone System, (at this rate one would expect operators to process close to between 15 and 20 items per hour), 2. The operators have little non-CAD work to execute (inputting CAD items represents over 90% of their work) and 3. The week under study witnessed rains every day of the week and there was hence a high volume of incidents on the CAD.

4.1.1.3 Response Time Variability by Incident Type

Thus far, the discussion has focused on issues such as the number of CAD items, their rate of arrival, and operator work efficiency, in terms of both the number of TIC items processed per time period per operator and the number of TIC items processed per number of CAD items entering the system. The following additional factors could also influence response time during a given hour of the day: 1. type of incident, 2. equipment malfunctions, 3. percentage of other work to which operators must attend (other than inputting CAD incidents) during that hour.

As stated previously, the percentage of non-CAD work is less than 10% of the overall work. In addition, this non-CAD work is distributed fairly evenly among the three workstations and hence cannot really explain the significant variations in response times among the different operators. During the week under observation for Wave 1, there were only two documented non-recurring TIC problems, documenting the same problem. These were of “critical” severity and had no effect upon response times. In fact, they occurred within the Acquisition sub-system of the TIC and concerned the unavailability of loop detector data outside the Contra Costa county area. Recurring TIC problems were not documented from January to July 1998. In any event, TIC problems, whether they were recurring or non-recurring, only very rarely interrupt or stop item processing for more than a few minutes. Thus, equipment malfunctions should not be considered a contributing factor to variations in response times. Aside from worker productivity, the last variable that could influence response times is the type of incidents handled by the operators.

The type of incident being processed by the operator is a variable that has only minor effect on operator response time. Indeed, the incident entry processes do not change or lengthen

considerably depending upon the type of incident being input. Whether the incident is severe or not, the operators still need to observe the CAD terminal, select items of interest and enter them into the TIC. The only difference between a severe and non-severe incident relative to response time is that the former would perhaps require slightly more typing or explanation in the description box of the Traffic Incident Manager window of the TIC and more checking of the CAD for updates on the incident. If one operator relative to another had to process mostly severe incidents, as opposed to the normal mix of incidents, one would expect his or her response time to be slower as the CAD terminal would need to be checked more often for updates on such incidents. However, since each operator rotates among workstations (see Tables 3a and 3b) and each workstation covers a whole area (such as the East Bay or Peninsula), each operator is exposed to different types of incidents throughout a shift and even more so throughout a given week. Thus, while incident types influence processing time to some extent they do not help explain variations in response times among operators.

One would expect that the response time would be smaller for serious incidents having a major impact on traffic. Figure 4 displays for Wave 1 results response time categories in increments of five minutes for the following major types of incidents handled by the operators (Wave 2 results are shown in Figures 5 (Monday through Friday) and 6 (Monday, Wednesday, Friday), again with Figure 5 based on the modified data set to account for the missing records on Tuesday and Thursday):

1125:	Unspecified roadway hazard (A = animal in roadway, C = in center divide, D = debris in roadway, V = stalled vehicle in the roadway)
1179:	Injury accident, ambulance rolling
1182:	Non-injury accident (vehicle/property damage only)
1183:	Accident—No details
Other:	All other incident types

As is clear from Figure 4, the distribution among incident types remains essentially the same for response times up to 20 minutes. Over 20 minutes, the “Other” incident type category doubles in size while the “1183” and “1182” categories shrink. Of particular note in the “Other” category are the incidents “1126”, “C/FIRE” (Car Fire), and “FLOOD”. “1126” type incidents do not impact traffic and should not be input into the TIC. In adjusting the number of CAD incidents, “1126s” were removed because that is TIC policy, yet were included here in the response time database since operators spent time processing them and entering them into the TIC²⁸. These three “Other” category incidents (1126, C/FIRE, FLOOD) consist of 6.6%, 9%, 8.6%, 6.4%, and 15.8% of all incidents from each of the response time categories from 0-5 minutes through 20 minutes or more, respectively. Thus, in the “20 minutes or more” category, approximately 16% of the whole database account for approximately 40% of the “Other” category. Unfortunately, these incident types are too general and do not allow the evaluators to separate incidents by severity groups and then measure response times.

²⁸ There were 26 “1126s” out of 708 in the response time database. Their average response time and standard deviation were 13.3 minutes and 11.5 minutes, respectively. Deleting them from the response time database would have reduced the percentage of incidents with response times greater than or equal to fifteen minutes by only a minimal amount yet it would also have reduced the work efficiency by a similar minimal amount.

Figure 4: Wave 1 Incident Type Distribution Per Response Time Categories

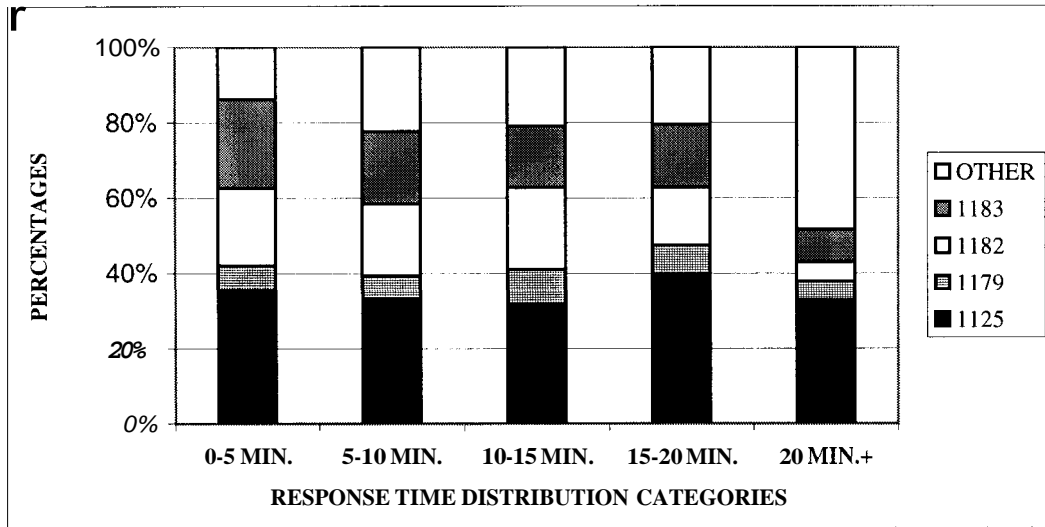


Figure 5: Wave 2 (M - F) Incident Type Distribution Per Response Time Categories

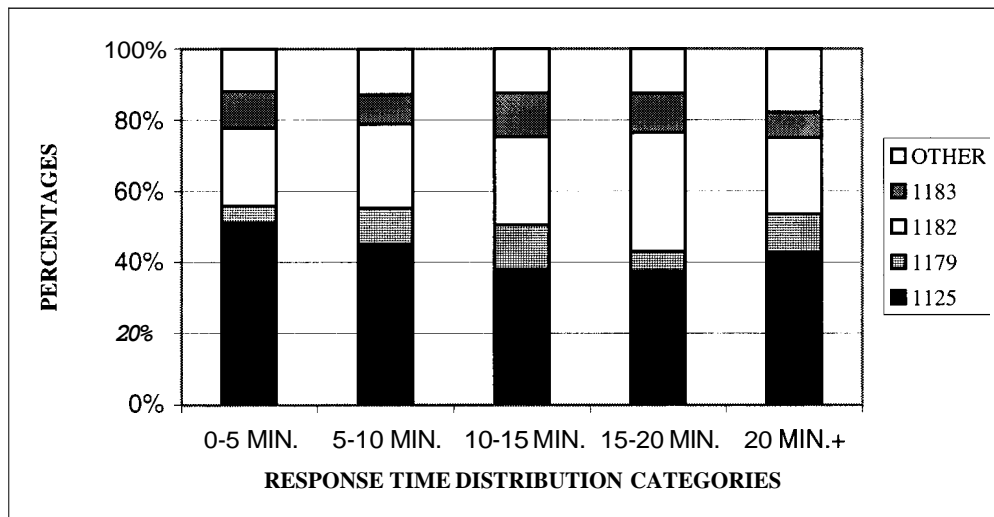
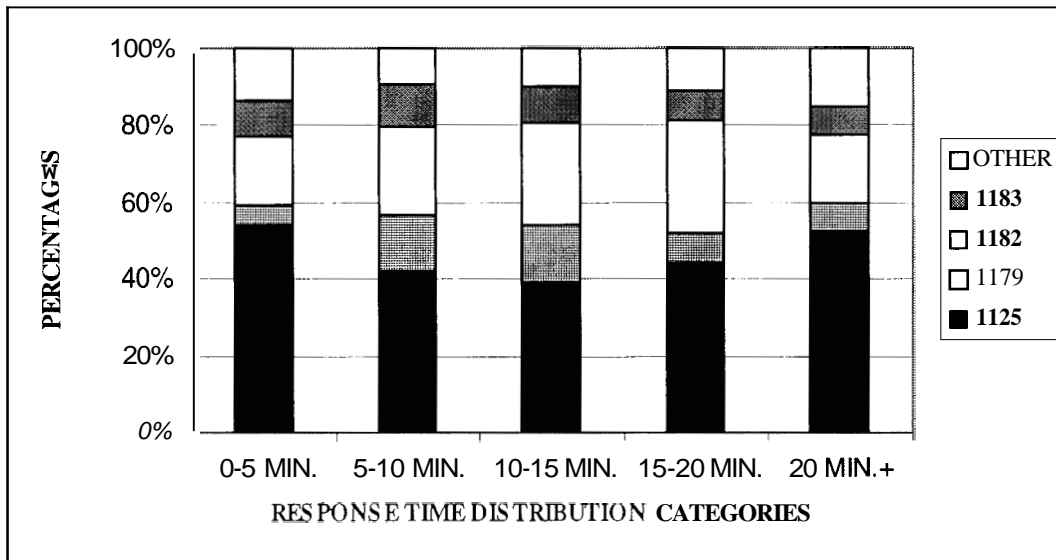


Figure 6: Wave 2 (M, W, F) Incident Type Distribution Per Response Time Categories



From the analysis above, it is the evaluators’ preliminary judgment that operator productivity is the primary explanation for the magnitude and variability of **CAD** to TIC response times. The following section describes the statistical hypothesis testing that was conducted to provide additional evidence concerning this assertion.

4.1.2 Statistical Hypotheses and Tests

The objective of the analysis described in this section is to demonstrate that operator productivity as measured by response time differs among the operators and that such differences are statistically significant. For Wave 1 the 708 entries in the **CAD** to TIC response time database were partitioned into groups according to the following categories: operator workstation, shift, and incident type²⁹. The resulting groups (where OWS, shift, and incident type are held constant) leave the day of the week as the primary variable, which of course, corresponds, to specific operators. Thus, operator productivity would then be the primary variable with which to explain response time, both in magnitude and variability. Groupings by OWS and shift are shown in Tables 4a and 4b. A similar partitioning was done for Wave 2 (Tables 6a and 6b).

To select an appropriate statistical tool to use initially depends on whether or not the underlying distribution of the data can be identified coupled with satisfying the assumption that the distribution may be approximated by the normal distribution (bell-shaped curve). Statistical tests also exist that do not depend on knowing the underlying distribution of the data, called non-parametric tests. Such a non-parametric test was selected for the analysis of these groups. The

²⁹ Partitioning by incident type for subsequent statistical hypothesis testing was not always possible due to an insufficient number of incidents within each cell describing a particular OWS, shift, and incident type. To circumvent this problem, the incident types for accidents (1179, 1180, 1181, 1182, and 1183) were pooled and considered a single category.

name of the test used was the Kruskal-Wallis Test. A brief description will be given here while full details may be found in either (8) or (9).

Each test is conducted for a fixed OWS (1,2,3), shift (A.M., P.M.), and incident type. Tests were also conducted in which just the OWS and shift were held constant. The variable is the day of the week providing five populations for Wave 1³⁰. The objective is to test whether the five population medians are all the same (Null Hypothesis) or are not all equal (Alternative Hypothesis). What this essentially says is that productivity is not equal across operators under the Alternative Hypothesis and is equal under the Null Hypothesis. The five populations are initially pooled and their response times ranked³¹. Following this ranking procedure, the five individual rank sums are calculated corresponding to each day of the week (specific operator). Finally, an expression, the Kruskal-Wallis statistic, is calculated that possesses approximately a known distribution (Chi-square). In statistical hypothesis testing, there are no absolute assurances, only likelihoods or probabilities. Thus one must also select, prior to performing the test, the probability that the Null Hypothesis will be rejected when, in fact, it is true (called the Type I Error). Customary practice places this value at 5%. All that remains to perform is a table look-up to identify the “critical value” corresponding to the chi-square distribution with a particular number for the degrees of freedom and a Type I Error of 5%. If the Kruskal-Wallis statistic is larger than this look-up value, then the Null Hypothesis is rejected, i.e., the medians for the five populations are significantly (statistically) different and productivity is not equal across operators.

Approximately thirty-five to forty individual tests were performed and covered each of the three operator workstations, the two shifts, specific incident types (e.g. accidents only, or traffic hazards only) as well as all types aggregated together and spanned different day-of-the-week combinations (Monday — Friday, Tuesday — Thursday, Monday — Thursday, Tuesday — Friday). Of these tests, 75% resulted in a rejection of the Null Hypothesis, i.e., a statistically significant difference among the population medians under study. Hence, operator productivity is a statistically significant parameter explaining differences among the observed response times.

Similar tests were performed for Wave 2 (Monday, Wednesday, Friday) and again, in general, the result indicated that operator productivity is a statistically significant parameter explaining differences among observed response times.

Furthermore, it should be noted that during the last set of TIC interviews, approximately one-third of the operators and one of the three supervisors mentioned operator performance as an area of concern in achieving TIC operational goals (10).

³⁰ The use of this test depends on the assumption that the populations are independent samples. Tables 3a and 3b show that the operator for Monday and Friday is the same person for each OWS and shift, which weakens the independence assumption. This can be avoided by omitting either Monday or Friday from the tests. Moreover, tests were also conducted for the three-day period of Tuesday, Wednesday, and Thursday to factor out the possibility of differences associated with weekend-related travel, i.e., on Monday and Friday.

³¹ Ties are handled by assigning the half-way point to each record in a set of tied records, e.g., if records 21 and 22 each have the same response time, then each is ranked “21.5”, if records 21, 22, and 23 each have the same response time, then each is ranked “22”.

4.2 TIC to TATS

The Operator Activity Report was the only data source providing actual³² TATS time using a single source of time (TATS clock) across all operators. However, this data source was incomplete, and contained TATS time for only 489 of the 708 CAD-generated incidents. Moreover, for 39 of the 489 records, TATS data was entered before TIC data, resulting in a negative value for the TIC to TATS time period and larger than expected CAD to TIC times. Several operators were responsible for these 39 records, which could have also affected their CAD to TIC times as well. For analysis purposes, only the remaining 450 records were used. From Table 7, there is variability in TIC to TATS response time across operators and for each operator. With the exception of the morning shift for OWS2 on Thursday³³, the TIC to TATS response times are within the range of 1.6 to 2.6 minutes. This is, nevertheless, large for the work involved. The overall mean and standard deviation for the 450 records is 1.8 minutes and 0.8, respectively.

**Table 7: Wave 1 TIC to TATS Response Times (Minutes)
Average (Standard Deviation)**

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
OWS 1					
Morning	No records	1.7 (0.2)	1.8 (0.3)	1.6 (0.1)	2.1 (0.3)
Afternoon	2.0 (0.4)	1.6 (0.4)	1.9 (0.4)	1.6 (0.2)	No records
OWS 2					
Morning	1.6 (0.3)	1.6 (0.2)	2.3 (0.8)	3.6 (4.8)	2.0 (0.4)
Afternoon	1.7 (0.3)	1.8 (0.4)	1.7 (0.2)	1.9 (0.3)	No records
OWS 3					
Morning	1.9 (0.4)	1.7 (0.7)	1.8 (0.7)	2.0 (0.4)	2.3 (1.0)
Afternoon	2.3 (0.6)	1.8 (0.2)	1.7 (0.6)	2.6 (0.5)	No records

For Wave 2³⁴ the Operator Activity Report was also incomplete, though only minimally so compared to Wave 1 with only 33 missing records. However, as in the case for Wave 1, some operators sometimes “TATed” before “TICing”, i.e., entered data into TATS before it was formally entered into the TIC database. This occurred for 136 incident records, resulting in a negative value for the computed TIC to TATS time and larger than expected CAD to TIC times for those operators who did this. Three out of nine operators were responsible for two-thirds of these records occurring on Monday, Wednesday, and Friday. For analysis purposes, only the

³² As previously mentioned TATS time from the OAR was adjusted to be synchronized with TIC and CAD time.

³³ This time period includes only six data points one of which is an extreme outlier and if removed, would reduce the average and standard deviation of the response time for this period to 1.4 and 0.7, respectively.

³⁴ This table is based on Monday through Friday data modified to account for the missing CAD records.

remaining 465 records were used. From Table 8, there is variability in TIC to TATS response times across operators and for each operator. Also note that there are three time periods during which there are rather large averages and very large standard deviations for the TIC to TATS time (Monday at operator work station #2 during the morning shift; Thursday at operator work station #2 during the afternoon shift; Friday at operator work station #3 during the afternoon shift). This is due to only four records with extreme outlier behavior. If they are removed from the database, then the response time averages and standard deviations during these three periods become, respectively: 1.6 (0.7); 1.2 (0.6); 1.4(0.8), which are much more in line with all other periods. The overall mean and standard deviation for the 463 records is 1.4 minutes and 2.9, respectively. The overall mean and standard deviation after the outliers have been removed, i.e., 461 records, is 1.2 minutes and 0.6, respectively.

**Table 8: Wave 2 TIC to TATS Response Times (Minutes)
Average (Standard Deviation)**

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
OWS 1					
Morning	1.1 (0.2)	0.9 (0.2)	1.1 (0.6)	1.3 (0.2)	1.4 (0.5)
Afternoon	1.0 (0.7)	1.3 (0.2)	1.1 (0.4)	1.3 (0.3)	1.1 (0.4)
OWS 2					
Morning	2.8 (3.8)	1.3 (0.3)	1.2 (0.4)	1.1 (0.5)	1.5 (0.3)
Afternoon	0.9 (0.4)	No records	1.3 (0.2)	1.7 (2.9)	1.3 (0.3)
OWS 3					
Morning	0.9 (0.1)	No records	1.3 (0.6)	1.3 (0.5)	1.4 (0.2)
Afternoon	1.6 (1.1)	No records	1.3 (----)	1.1 (0.2)	8.5 (18.7)

5. CONCLUSIONS

The response time analyses conducted over two waves indicate overall that for Wave 1 from the CAD to the TIC and from the TIC to TATS the mean response times are 10.2 minutes and 1.8 minutes, respectively. For Wave 2 restricted to Monday, Wednesday, and Friday analogous times are 10.1 minutes and 1.4 minutes³⁵. Thus there was a small decrease in the overall CAD to TATS response times between the two waves.

Operator response times have generally remained fairly constant and stable during the Field Operational Test with significant differences in response times across operators. The findings indicate that improvement is needed in both overall operator work efficiency and operator

³⁵ The CAD to TIC times for both waves are slightly different than reported in an early section of this report. This is due to the fact that the estimates reported in this section have removed those records corresponding to those operators who “TATed” before they “TICed”. Otherwise, the CAD to TIC plus TIC to TATS response times for these records would have in essence double counted the time required to prepare a message for TATS.

response time. However, a formal operator quality control plan was not implemented until March 1998. Furthermore, based on frequent evaluation visits to the TIC throughout the FOT, interviews with operators over the course of the FOT, and a lack of operator performance reviews until March 1998, evaluators believe the findings from these two Waves are reflective of operator performance that have existed throughout the FOT.

Other factors were also examined to assess their influence on operator response times including the number and type of incidents (e.g., traffic hazard, accident with major injuries) reported by the California Highway Patrol, time of day, the location where the incident was processed, i.e., the specific geographic workstation, level of operator work experience at the TIC, incident arrival rate, operator work-break periods, weather conditions, and system software and hardware problems (documented by operators). These factors, however, played only a minor role in influencing response times.

Numerous operator work activities also affect operator response times and help provide the fuller context within which response times were assessed. These activities included attempts to verify an incident, disruptions caused by their own and other operators' shift changes, operator call-checking into the phone advisory system for quality control purposes, updating an incident already entered into the system, searching for multiple listings for the same incident or those not delaying traffic flow. However, these activities were difficult to isolate and individually quantify their contribution to operator response times.

It is anticipated that once TravInfoTM enters its more permanent and stable phase with a new system manager, operations will soon become substantially more automated and this should have a significant impact on reducing operator response times as well as increasing overall operator productivity. It is recommended that once these changes are implemented, subsequent operator response time assessments be made. Automating operations coupled with the much stricter operator quality control measures that were put in place near the end of the FOT should combine to make Traveler Information Center operations more like the "timely" undertaking it was intended to be.

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