The Use of Operational Models to Evaluate Construction Staging Plans, A Case Study

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ABSTRACT

Construction staging has traditionally been a process of identifying the critical “measured” demand and designing staging plans to ensure that sufficient capacity exists within the construction zone to meet that measured demand. A more robust approach would take into account the true demand and consider the flow of traffic as a system with various interactions at work. Operational simulation models meet these needs and permit the analysis of dynamic, time-sensitive traffic phenomena, where vehicles travel though the network and interact with each other in response to various roadway characteristics and conditions.

This paper presents a case study of a construction staging project, based upon a four-step methodology that incorporates both traffic engineering analysis and the development of operational simulation models to evaluate construction staging plans. This process was able to clearly distinguish between two alternative construction staging schemes. This demonstrates that using a well-defined simulation model can achieve an accurate and reliable method for evaluating construction staging plans.

A unique aspect of the study was a trial field evaluation of both proposals, which provided the opportunity to verify both methodology and analysis results. Results for the trial validated both the simulations and the traffic engineering evaluation, many of the conclusions, and provided some insight into travel behavior.

INTRODUCTION

Road construction, like traffic congestion, has become a part of daily life for many motorists. Along with the queueing and traffic slowdowns that are symptomatic of chronic traffic congestion, narrow and shifting lanes, delineated by lines of orange cones and barrels, have become a fixture on the American motoring landscape. Drivers often become confused, frustrated, and impatient with the unfamiliar and difficult conditions inherent in construction areas, and safety is a growing concern. In 1999, 872 people died in construction zones accidents, more than 700 of them motorists or passengers traveling through work zones. (1)

Things are likely to get even worse. To address the issues of traffic congestion and deteriorating roads and bridges, transportation spending has increased in recent years. According to data from The Road Information Program, spending on U.S. roads grew from $49 billion in 1997, to $58 billion in 1999, to a projected $65 billion in the current fiscal year. (2) So help is on the way, but it comes at a cost in the form of even more construction and detours, and the additional delays associated with them.

Construction staging alternatives present tradeoffs among schedule, cost, safety, value and convenience. Project managers must weigh these and other factors while attempting to minimize the disruption experienced by motorists. In addition to shifting work to off-peak hours, reducing work zone speed limits, and better enforcement of speed and safety infractions, it has become imperative to design safer and more efficient construction staging and maintenance and protection of traffic plans. This paper presents a case study of a method of effectively evaluating the impact of alternate staging plans taking into account the operational and fluid nature of traffic through construction zones. What is unique about this method is the ability to present a real-time running visual of the alternatives as well as tabular and graphical performance measures for the project manager's inspection.

Basic speed-flow relationships determine effective roadway capacity and a variety of conditions – including road construction - may contribute to reductions in capacity. Level-of Service analysis is the standard measure of roadway performance. Specific studies of work zone traffic and Level-of Service indicate a reduction in capacity related to the intensity of work that is undertaken, the intensity of the reduction is in turn determined by individual factors including lane closures and lane width reductions. (3)

Construction staging has traditionally been a process of identifying the critical "measured" demand and designing staging plans to ensure that sufficient capacity exists within the construction zone to meet that measured demand. Level-of Service analysis is then undertaken to gauge the ability of the construction zone to accommodate the measured demand, by taking into account the cumulative affects of lane closures, lane-width reductions, and other factors, and calculating the effective capacity. (4) However, this method treats demand as isolated points, whereas in actuality traffic flows as a system where throughput is the result of both upstream and downstream conditions. Traffic engineering techniques applied to point-based demand alone may therefore not be indicative of actual conditions – as the measured demand may be lower than true demand due to limitations in throughput related to queueing, merging, weaving, geometry, or other prevailing conditions within the study area.

Vehicles enter the construction staging area at specific times and with specific destinations in mind, negotiate their way through the roadway network, interacting with other vehicles as they compete for use of a limited resource: highway capacity. The outcome, reflected in terms of travel time and potentially adverse conditions that may include delays and queueing, is the result of all of these various interactions. A more robust approach to construction staging analysis would take into account the true demand and consider the flow of traffic as a system with various interactions at work. Operational simulation models meet these needs and permit the analysis of dynamic, time-sensitive traffic phenomena, where vehicles travel though the network and interact with each other in response to various roadway characteristics and conditions.

This paper proposes an alternative methodology to review construction staging alternatives based upon a four-step process:

1. ***Targeted scope of investigation*** – the key to completing the overall effort within the usual constraints (time, budget, schedule) is maintaining a narrow focus on the study area and limiting the questions the analysis will attempt to investigate;

2. ***Timely data collection to identify true demand*** – the data collection program should be designed to distinguish between the critical *measured* demand and the *true* demand within the study area. This will contribute to a better understanding of the actual load on the facility and the underlying origin-destination (O-D) relationships, rather than simply reflecting the prevailing throughput (or measured demand); it is crucial to understand that throughput and demand are not equal, particularly under congested conditions;
3. ***Preliminary traffic engineering analysis*** – traffic engineering analysis should take place prior to development of the simulation model, and following data collection. This analysis should review the proposed construction plans for fatal flaws and apply Highway Capacity techniques to estimate roadway capacity. The fatal flaw analysis will determine whether all through movements are maintained and that safety issues have been thoroughly investigated. Capacity of the freeway links for the simulation should be derived from the HCS evaluation, ensuring consistency among the various levels of the analysis.
4. ***Performance measures directly relevant to motorist experience*** – performance data extracted from the simulation should be reflective of the actual travel experience, which is consistent with the stated goal of minimizing the impact of construction on the general public. Measures such as average travel time and queue formation contribute to a better understanding of construction zone dynamics and a spreading or lengthening of the peak period.

The work effort for this case study was based upon the four-step process described above. The evaluation was undertaken with a limited schedule necessitated by a proposed staging change, and a limited budget. The work effort was designed to focus on the key questions and issues needed to quickly but effectively evaluate a number of staging proposals. The bulk of the simulation and analysis work was completed within one week. The case study begins with a problem statement and description of the study area and proposed project. The evaluation included a data collection effort and related traffic engineering analysis. The operational simulation model and performance measures were designed to meet the constraints of the study and evaluate the relative merits of the proposed construction staging alternatives. A unique aspect of the study was the use of a trial evaluation to verify and validate results of the operational modeling analysis. Finally, a series of conclusions and lessons learned are presented.

PROBLEM STATEMENT

The study area is an eastbound section of Interstate 80 near Saddle Brook, New Jersey, located in Bergen County between Interchanges 62 and 64. I-80 is the principal east-west travel route in this section of New Jersey, the making it the most heavily traveled section of I-80 in the state. Although several parallel arterial routes exist, there are no suitable limited access alternatives in the vicinity. I-80 is already severely congested during the peak periods, and any significant reduction in throughput could adversely affect travel through the region, so it is imperative that construction-related impacts be kept to a minimum. I-80 is a vital travel route for commuters, heavy trucks, and recreational travelers alike, serving both local origins and destinations and longer-distance through traffic between New York, New England, New Jersey, and Pennsylvania. Connecting ramps provide access to and from the Garden State Parkway (GSP) on the western end of the study area and Route 17 and the New Jersey Turnpike to the east. The average daily traffic volume in the study area was nearly 122,000 vehicles in 1999.

The existing roadway configuration is depicted in Figure 1. Eastbound I-80 has a five lane cross-section approaching the Collector-Distributor (C-D) Road, which starts at Interchange 62 and provides access to and from the GSP and locally to Saddle River Road. Parallel to the C-D road, I-80 narrows to 4 lanes and then to a split configuration consisting of 2 express lanes and 2 local lanes, divided by a median. The express roadway bypasses most local exits and provides direct access to the New Jersey Turnpike and George Washington Bridge, while the local roadway provides access to a series of local interchanges. Traffic from the GSP enters the I-80 local roadway via ramp from the C-D road; further downstream to the east, a crossover ramp connects from local to express. Access to NJ Route 17 is only possible from the local roadway at Interchange 64. All lanes of I-80 through the study area are 3.66 m (12 ft) wide with consistent 3.66 m (12 ft) shoulders.

The project proposes to improve a section of Interstate 80, including roadway widening, noise wall erection, and bridge deck replacement. All of the improvements would be applied to the eastbound portion of the local roadway. As part of the New Jersey Department of Transportation's (NJDOT) design development process, traffic control and construction staging plans were developed according to Part VI of the *Manual on Uniform Traffic Control Devices* and to Department standards. (5) Analysis by the Department determined the existing four-lane configuration – two lanes in the local roadway, two lanes in the express roadway – must be maintained during construction, based on the

existing travel volumes. The express roadway would remain at full capacity (2x3.66 m (12 ft) lanes with shoulders), and the local roadway would remain open but reduced to 2x3.36 m (11 ft) lanes without shoulders but with three emergency pullover/breakdown areas. With the exception of the reduced lane width and shoulders, roadway configuration and operation would be essentially the same. Three major construction stages would be required to complete the project. This staging plan is referred to as Contract Staging Plan (see Figure 2).

Upon awarding of the construction project, the Contractor developed an Alternative Staging Plan that proposed to perform all bridge work in one stage, thus shortening the overall construction period by several months. As depicted in Figure 3, the Alternative Staging Plan would close the local roadway during construction and merge all eastbound traffic to the express roadway, which would be reconfigured to 2x3.36 m (11 ft) lanes without shoulders. The ramp from C-D road to the local roadway would be extended to the express roadway to allow continuous access from the GSP to eastbound I-80. This alternative would provide no breakdown areas for disabled vehicles.

The Department then requested a review of the Alternative Staging Plan by the design consultant. The consultant conducted a traffic engineering evaluation that concurred with the Department's determination and led to the need to develop simulation models of the two staging alternatives. These simulations would demonstrate visually the anticipated operational breakdowns predicted by the traffic engineering evaluation. This review process was based on the four-step methodology, which was applied, as described below.

1. ***Targeted scope of investigation*** - the simulation was designed to evaluate the construction staging area, a section of eastbound I-80 between Interchanges 62 and 64. The study area was thus limited to the construction zone, while allowing for sufficient stacking capacity to accommodate worst-case traffic queues and all potential travel paths. The adjacent arterial network was excluded. This is consistent with the study goals: minimizing disruption experienced by motorists means accommodating current traffic demand without a significant spatial or temporal shift.
2. ***Timely data collection to identify true demand*** - a data collection effort was designed to support highway capacity and traffic simulation analysis. This included two days of traffic counts, speed and delay runs, and observation of queue formation and length. Count locations included critical entry and exit points to and from the construction zone simulation area: all eastbound I-80 lanes entering the study area, the separate local and express facilities, the entrance ramp from the Garden State Parkway, the C-D road, and the exit ramp from C-D road to Saddle River Road. Counts were taken sufficiently upstream of queue formation to capture the true demand.
3. ***Preliminary traffic engineering evaluation*** - included fatal flaw analysis of staging plans and traffic flow, and traffic engineering evaluation to determine roadway capacity and throughput. Construction staging plans for the Alternative Staging Plan were provided to the design consultant. These were reviewed to ensure that all existing traffic movements could be accommodated and that adequate worker and motorist safety precautions were considered and incorporated. No fatal flaws were found, although the lack of shoulders or breakdown areas leaves no way to recover from an accident or disabled vehicle. A capacity analysis using procedures from the 2000 Highway Capacity Manual was used to determine whether a three-lane express roadway could accommodate the prevailing demand. Based on this evaluation, it was determined that the three-lane cross section was insufficient to meet the measured demand - the total eastbound peak period traffic volume on I-80 would be at or above capacity. Further downstream, the entrance of more than 1,000 additional vehicles from the CD-Road/GSP to I-80 during the peak hour would considerably worsen the situation.
4. ***Performance measures directly relevant to motorist experience*** - The measures of effectiveness and performance employed to evaluate the staging alternatives were consistent with the goal of focusing on a limited scope of issues within a narrowly defined study area. Although restricted in number, the selected measures reflect a comprehensive range of evaluation methods. These include measures of average speed, travel time, queue length, and vehicle throughput; some are direct outputs from the INTEGRATION model, others derived through observation of the simulation runs.

TRAFFIC SIMULATION

The INTEGRATION operational model platform was chosen to simulate traffic operations, both for its ease of use and implementation and its numerous measures of effectiveness. INTEGRATION is an operational model that

provides for the replication, or simulation, of roadway operations such as congestion, queuing, travel times, lane changing and weaving to provide insight into the benefits and shortcomings of a design concept and yield realistic expectations of performance. Operational simulations provide the ability to assess a broad range of "what if" scenarios and garner a wider and more accurate range of performance measures for comparison among alternative design and operational scenarios than traditional travel demand models. These capabilities make INTEGRATION an ideal platform to evaluate the relative merits of the two alternative construction staging plans that form the subject of this study.

Operational models are interactive and graphical in nature. They allow customers to "see" the facility being evaluated, and "watch" the vehicles react to changing conditions resulting from an improvement concept. These qualities have proven to be extremely helpful in public outreach activities, as they transform the model's technical plots and databases to easily understood and interpreted images. These features help build faith, as the process is no longer just a "black box".

An operational model such as INTEGRATION can also generate various measures of effectiveness. Travel times by vehicle type can be obtained, so if a link happens to be mixed mode (i.e., autos, buses and trucks) it is possible to check the operating conditions of each. INTEGRATION also facilitates estimation of traffic "backups" in terms of length of queue, length of time that a queue exists, duration and intensity of the peak period, and visual observation of queue formation and dissipation. Another factor that can be evaluated is the roadway's ability to handle and dissipate traffic "incidents", such as a partial or full lane closure for a period of time, which could be attributed to an incident or construction.

A rigorous process was used to develop and calibrate the existing conditions model and then prepare and evaluate the two staging alternatives. A GIS-based network editor was used to build the network and capture accurate roadway geometry and point-to-point link distances. Field visits conducted during the data collection process and construction staging plans were used to verify the coding of roadway characteristics (lanes, speed limit, etc.) and configuration. Finally, data from the NJDOT 2001 Straight Line Diagrams was used as a quality control tool to verify accurate coding of lanes, distances, and roadway characteristics and configuration. The edited network was then exported to an ACSII format and converted to INTEGRATION-compatible nodes and link files using custom software applications. Capacity of the freeway links was derived from the HCS evaluation performed by the Traffic Engineering staff, ensuring consistency among the various levels of analysis.

The simulation was designed to evaluate the 6:30-9:00 AM peak period. Since origin-destination (O-D) data was not available, the trip table was synthesized from traffic counts gathered during the data collection effort. These data indicated a peak hour of 7:30 to 8:30 AM. The network consisted of seven entry/exits in the corridor. The first step was to generate traffic volumes at all locations (links and zones) along the corridor. Traffic counts were "flowed" from one major junction to another. After the counts were flowed there were still some gaps where traffic was unaccounted for or assumptions on distribution needed to be made. Initial distribution assumptions were made at junctions based on estimations of traffic patterns and flows extracted from the travel time delay information. This process was acceptable because of the local scope of the corridor and small size of the network (two origins and five destinations).

INTEGRATION allows for O-D trip data pairs to be entered as individual records with specific start and stop times, the total number of trips, and up to five different vehicle types. A factor indicating fully random headways was entered for each O-D pair. The final trip table was a two-purpose (auto and truck) trip table with five 30-minute intervals. Dividing the traffic flow into 30-minute increments enables INTEGRATION to simulate the buildup, queueing, and dissipation of traffic over the course of the 2½-hour peak period as demand changes in both intensity and pattern. This pattern is typical of peak period travel.

Three sources of data collected for the Traffic Engineering evaluation were used to calibrate to existing conditions: traffic counts, average travel speed, and queueing observations. The calibration was determined to be within acceptable limits. The calibrated trip table was used for each of the three simulations: existing conditions, Contract Staging Plan, and the Alternative Staging Plan. This facilitated a direct comparison of system performance among the three conditions given a consistent level of demand, both by time of day and total vehicles entering the network, and allowed planners to evaluate the ability of the proposed staging to accommodate the same level of travel

demand as currently exists in the study area. This is consistent with one of the goals of construction staging – to minimize the disruption to the motoring public.

SIMULATION RESULTS

Table 1 summarizes the results and presents a direct comparison among existing conditions, the Contract Staging Plan, and the Alternative Staging Plan.

Average Speed is a direct output from the INTEGRATION Model and represents the average speed of all vehicles traveling through the corridor over the duration of the simulation (6:30-9AM). For the existing condition simulations, the average travel speed was 36 MPH. The average speed for the Contract Staging Plan slowed by less than 10% to 33 MPH and by more than one-half to just 16 MPH for the Alternative Staging Plan.

INTEGRATION provides average **Travel Times** for all O-D pairs. Two travel time measures were evaluated: (1) through trips on the I-80 portion of the simulation network, a distance of about 5.8 miles within the simulation originating west of Interchange 61 and destined east of Interchange 64; and (2) trips originating from the GSP and destined eastbound on I-80, a distance of about 4.6 miles. Results of travel time analysis for the I-80 trips were similar to those for Average Speed, at 12 minutes for the existing condition, 12.5 minutes for the Contract Staging Plan and more than twice as long for the Alternative Staging Plan, at 25 minutes. More congestion occurred for GSP to I-80 through trips, where slowing occurred at two merge points, first at the merge of the GSP exiting traffic with the C-D road, and then where the C-D road merges with I-80. The I-80 merge is particularly critical, as more than 1,000 vehicles enter the Interstate at this point during the peak hour. Travel times slowed significantly from 6.5 minutes under existing conditions to 10 minutes for the Contract Staging Plan and 22 minutes for the Alternative Staging Plan.

Maximum Queue Length was derived from on-screen observation of the simulation model runs. In general, the queue was measured starting at the principal merge/diverge point. For both the existing condition and Contract Staging Plan simulations, this point was the diverge of the four lane I-80 mainline to separate local and express facilities. The closing of the local roadway under the Alternative Staging Plan leads to queueing at two “choke” points: the first at the merge of the 4 lane I-80mainline to 3 lanes on the express roadway and further downstream where the three express lanes split back to express and local at the temporary crossover which shortly thereafter provides access to the Route 17 exit ramp at Interchange 64. Under this alternative, two separate queues form initially, one at each choke point. The two queues gradually expand and eventually meet to form a single queue at least 4 miles in length. This compares to I-80 traffic queues of ¾ mile under existing conditions and 2+ miles for the Contract Staging Plan.

The final performance measure is **Total Vehicle Throughput**, a measure of supply (capacity) vs. demand (vehicles entering from the west), which represents the total number of vehicles able to pass through the study area during the peak period. Although some travelers will change routes or switch modes because of construction-related delays, most will continue to travel along I-80. Any reduction in throughput therefore indicates trips that are forced to the shoulder periods by congestion and result in a spreading of the peak period. Although the simulation indicates negligible change in throughput for the Contract Staging Plan, the Alternative Staging would reduce throughput by nearly 3,000 vehicles during the 2 ½ hour peak period. This is a significant indicator that the duration of traffic congestion would increase with this proposal.

To summarize these data, the Contract Staging Plan clearly creates less delay for motorists than the Alternative Staging Plan. Based on data from the simulations, the Alternative Staging proposal would reduce the average travel speed by one-half, add 12 minutes to the travel time through the project work area, increase the longest queue length by 2 miles, and reduce throughput by about 3,000 vehicles as compared to the Contract Staging Plan. The lower throughput of the Alternative Staging proposal would also lengthen the peak period by forcing travelers to the shoulders of the peak, consequently increasing the duration of congestion.

TRIAL EVALUATION TEST RESULTS

A unique aspect of the study effort was the opportunity to compare the two staging alternatives in a trial evaluation period. The construction zone was set up as designed in the Contract Staging Plans for one week, then set up as the

Alternative Staging Plan for an additional week. The Consultant monitored and evaluated traffic conditions during each trial, including traffic counts, speed and delay runs, and videotaped field observations. This in turn allowed the Consultant to verify the results of the simulations and thereby gauge the accuracy and effectiveness of the applied methodology for evaluating construction zone staging plans. Data collection for both trial evaluations was conducted during the AM peak period in July of 2001. The program allowed for two days of counting for each alternative at locations similar to the April counting program.

In general, the traffic volumes observed during both phases of the trial evaluation were at least 10-15% lower than the pre-construction (existing conditions) data that supported the initial round of traffic engineering and operational modeling analysis. Several causal factors may have contributed to the lower observed traffic volumes. First, the trial evaluation and associated counts were collected in July, and may be subject to both seasonal fluctuation and the impact of the mid-week July 4th holiday. However, a review of traffic count station data from 1998 and 1999 at Milepost 54.72, the location nearest the study area for which annual data was available, indicates little seasonal variation among for the months of April, July, and September, so the impact of the seasonal factor is inconclusive. A second reason may be related to the way in which the staging trial evaluation was publicized. Some form of public notice was released prior to the start of the trial. Motorists may have anticipated additional traffic congestion and adjusted their travel time, route, or mode in response. Regardless of the cause, it was expected that the lower overall level of demand would understate the potential delays and congestion that may occur through the construction zone, and that volumes will return to the higher levels as previously recorded in April.

Comparison of the trial evaluations vs. the existing conditions was based primarily on travel time (for I-80 through trips and GSP to I-80 through trips), and observed queue length. Given the lower observed traffic volumes, results of the Contract Staging Plan were very similar to the existing condition data and showed little evidence of degradation in performance.

It can be reasonably concluded, therefore, that the Contract Staging Plan can accommodate the level of demand present during the trial evaluation period. However, no comparison was available for the higher levels of demand experienced during the April data collection effort. For example, the short queue that typically occurs at the approach to the I-80 local-express split during peak demand did not occur during the trial evaluation of the Contract Staging Plan.

In contrast, the trial evaluation of the Alternative Staging Plan demonstrated degraded performance compared to the existing conditions in the study area, despite the lower overall traffic volumes. Travel times for the Alternative Staging Plan were 10 minutes longer than existing conditions for I-80 through trips and 6 minutes longer for GSP to I-80 through trips. Traffic queues on the I-80 mainline were observed at both “choke” points associated with the Alternative Staging Plan, similar to those observed during the INTEGRATION model runs. Both queues extended for a distance of at least 1.5 miles, but unlike the model runs they did not meet to form a single queue. The queues began to form at about 7:30 AM, and dissipated at about 8:45 AM. This observation suggests that the total demand for the three-hour period was satisfied during the period, although not necessarily as the demand arrived. The data also indicate an earlier start to the peak hour, moving back from 7:30 to 7:00 AM, as drivers react to changing travel conditions and adjust their schedules and travel times accordingly.

The trial evaluation therefore reasonably validates the predictions made by the operational simulations. Despite the reduction in demand between the April data and the July trials, field observation of travel times reported consistent travel time differences, with a 10 minute increase for I-80 through travelers and a 6 minute increase in travel time for GSP to I-80 travelers. This compares to model-generated travel time increases of 13 minutes and 15 minutes, respectively, for higher demands. These data are depicted in Table 2. The field observations also confirm that travel times are greater for the Alternative Staging Plan than for the Contract Staging Plan. Higher demand volumes, which would be expected in the fall months when construction is expected to begin, would likely result in travel time differences similar to or greater than the model predicted results. Queue formation also validates simulation model results for the Alternative Staging Plan. The model projects queue formation at the two major “choke” points for this alternative: one at the I-80 mainline merge from four lanes to the modified three lane express roadway, and the second at the diverge from three express lanes back to express and local at the temporary crossover. In the simulation these two queues grow and eventually merge together to form a line of traffic at least four miles in length. During the trial, two separate queues of at least 1.5 miles in length did form, but due to the lower overall

demand, the two did not meet to form a single queue. So the pattern of queue formation does validate, although not perfectly replicate, the model results.

Several important differences were noted in travel behavior between the simulation and the trial evaluations. Compared to the model-generated traffic volumes for the Contract Staging Plan, the combined local-express volume prior to the Ramp CD merge was very similar: 4,810 vph in the model vs. 4,765 vph in the trial evaluation. One difference is the split in volumes carried on the local and express facilities in this section of I-80. The model retains the same local-express split as the April traffic counts and indicates more demand and congestion on the local roadway, while the trial observation captured a more equal split between the two facilities, So while the model predicts a worst-case scenario which does not account for shifting of local traffic to the express roadway, it appears that some motorists do adjust and begin to shift based on roadway conditions. In addition, the model runs indicated higher volumes and more congestion of the ramp from the GSP to the C-D road, the C-D road itself, and the ramp from the C-D road to I-80. This could be due to the lower overall volumes observed in the trial evaluation or an underestimation of the capacity of the C-D used for the simulation. Consequently, although the travel times for the GSP to I-80 trips did increases, the margin was only 6 additional minutes, not 15 as projected by the model runs.

CONCLUSIONS

This paper has presented a case study of a project to evaluate two alternative construction staging schemes. The evaluation was based on a four-step process that provides a more robust alternative the more traditional methods used to develop and review construction staging plans. The four-step process includes: A targeted scope of investigation, Timely data collection to identify true demand, Preliminary traffic engineering analysis, and Performance measures directly relevant to the motorist experience. The effort involved both traffic engineering analysis and the development of operational simulation models to evaluate their relative merits and the ability of each to accommodate the existing traffic demand. The project was undertaken with a limited schedule, and the work effort was designed to focus on the key questions and issues needed to quickly and effectively evaluate the proposal. The simulations were similarly focused exclusively on the study area. Despite the limitations, a rigorous process was used to develop and calibrate the existing conditions model and then prepare and evaluate the two alternatives.

The simulations confirmed the preliminary traffic engineering evaluation, and clearly established the shortcoming of the Alternative Staging Plan, which was projected to lower average travel speeds through the project area, increase travel times, length queues, reduce vehicle throughput, length the duration of congestion and spread the peak to shoulder periods. As a consequence, some travelers may choose to avoid the construction area and potentially add congestion to parallel and alternates routes.

A unique aspect of the project was the opportunity to conduct a trial evaluation of both proposed alternatives. Each configuration was set in place for one week and additional data collection was undertaken. Although the demand volume counted was lower than previously recorded in support of the traffic engineering and modeling effort, many of the observations and performance measures were consistent with the results of the simulations. The trial therefore served to validate both the performance of the traffic simulations and the conclusions they supported. Travel conditions during construction should be expected to be worse that those experienced during the trial period, if the demand returns to levels experienced during the initial traffic counts conducted earlier in the year.

It also confirmed the effectiveness of visualization models. The display of the running simulation of one alternative versus the other proved very effective in presenting the issues, results, and conclusions to transportation decision makers.

This effort has demonstrated the ability to effectively evaluate construction staging plans even under the confines of limited time and the need to consider the impact to the motoring public when undertaking road construction projects. We feel that the methods tested for this case study are more accurate than standard static evaluation techniques and that this type of evaluation method is applicable to any construction zone project where one needs to evaluate alternate staging plans.

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LIST OF FIGURES

LIST OF TABLES

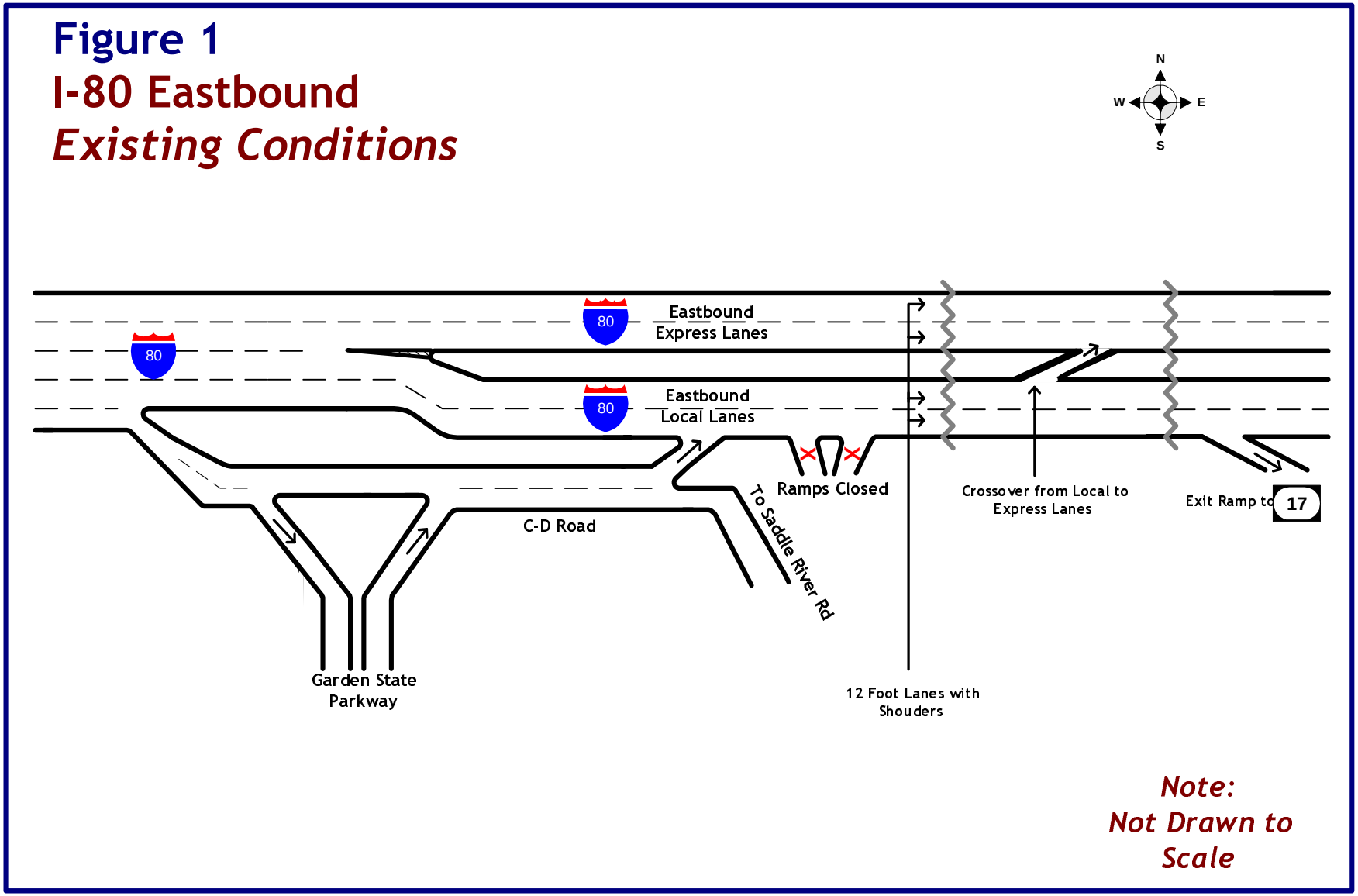

FIGURE 1 I-80 Eastbound Existing Conditions

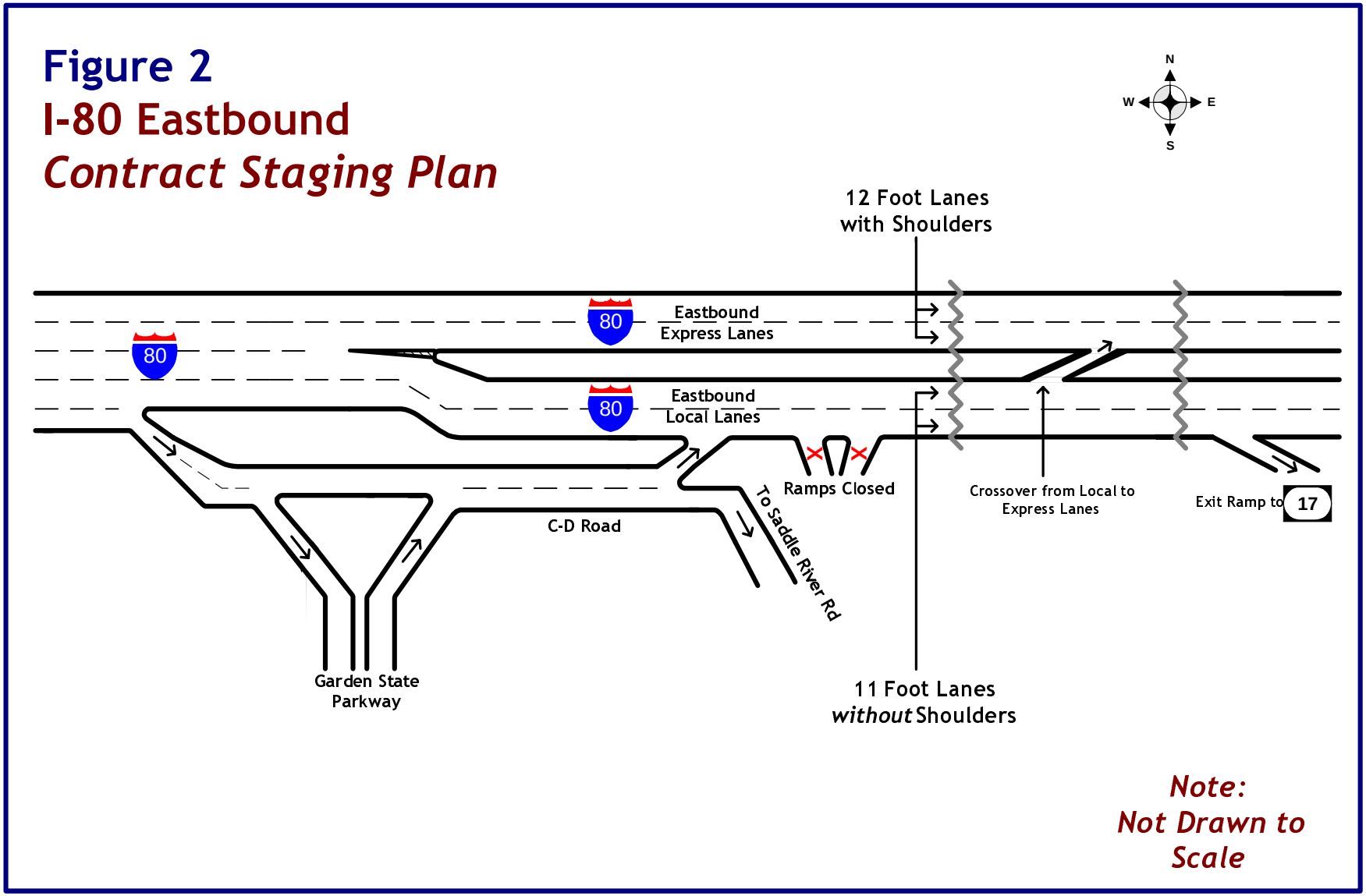

FIGURE 2 I-80 Eastbound Contract Staging Plan

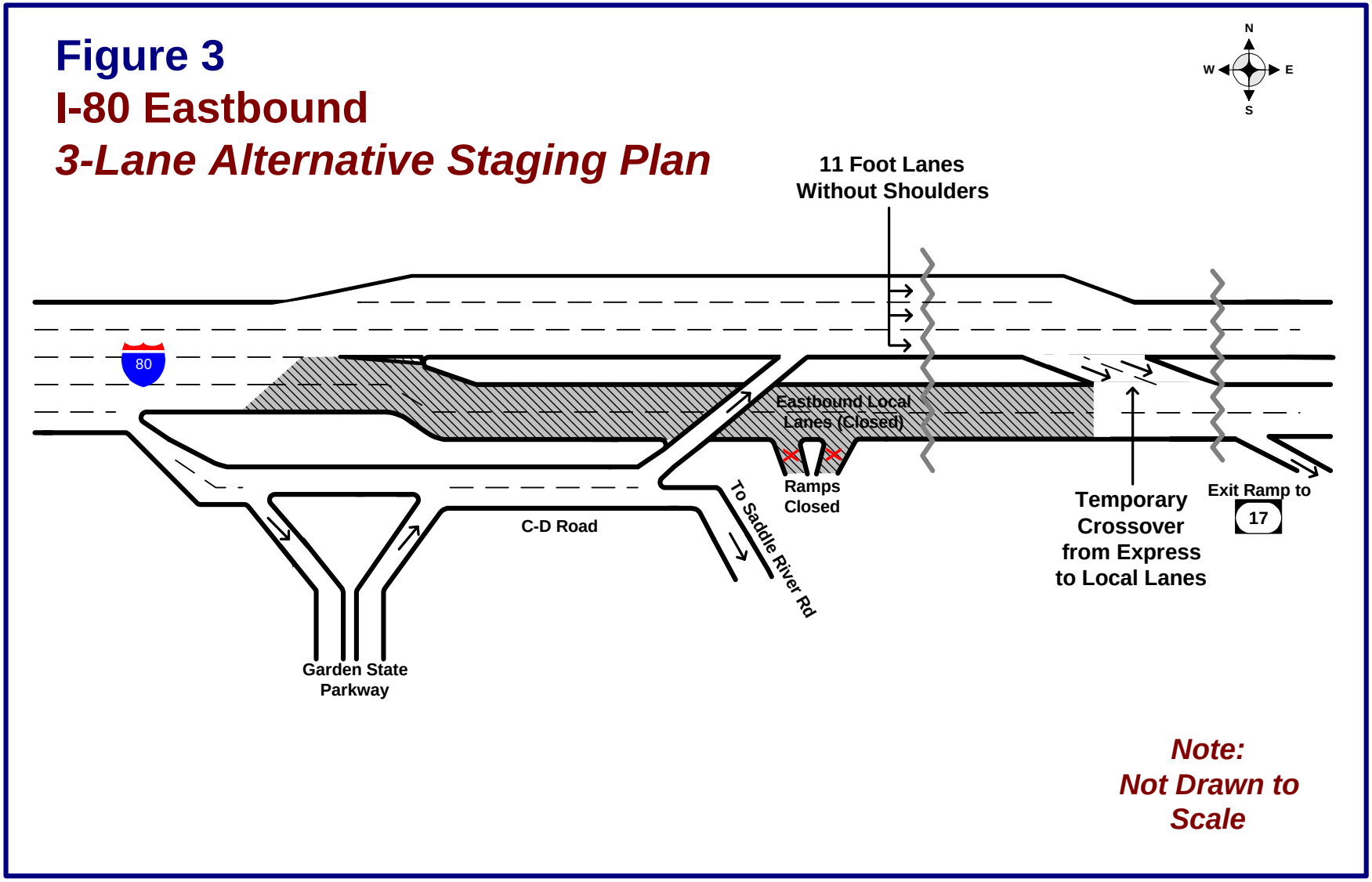

FIGURE 3 I-80 Eastbound 3-Lane Alternative Staging Plan

TABLE 1: Summary of Operational Model Results

	Existing Conditions	**Contract Staging Plan**	**Alternative Staging Plan**
Average Speed (MPH)	**36**	**33**	**16**
Travel Time for I-80 through trips (approximate in minutes)	**12**	**12.5**	**25**
Travel Time for GSP through trips (approximate in minutes)	**6.5**	**10**	**22**
Maximum Queue Length on I-80	**¾ miles**	**2+ miles**	**4+ miles**
Total Vehicle Throughput 6:30-9:00 AM	**13,600**	**13,450**	**10,750**

TABLE 2 Comparison of Contract Staging Plan Trial Evaluation vs. Operational Model Results

	Existing Conditions	**Contract Staging Plan**		**Alternative Staging Plan**	
		Model Results	**Trial Evaluation**	**Model Results**	**Trial Evaluation**
Travel Time for I-80 through trips (approximate in minutes)	**12**	**+0.5**	**Same as existing**	**+13**	**+10 minutes**
Travel Time for GSP to I-80 through trips (approximate in minutes)	**6.4**	**+3.5**	**Same as existing**	**+15.5**	**+6 minutes**
Maximum Queue Length on I-80	**¾ miles**	**2+ miles**	**Same as existing**	**4+ miles**	**2 Queues, each at least 1.5 miles in length**