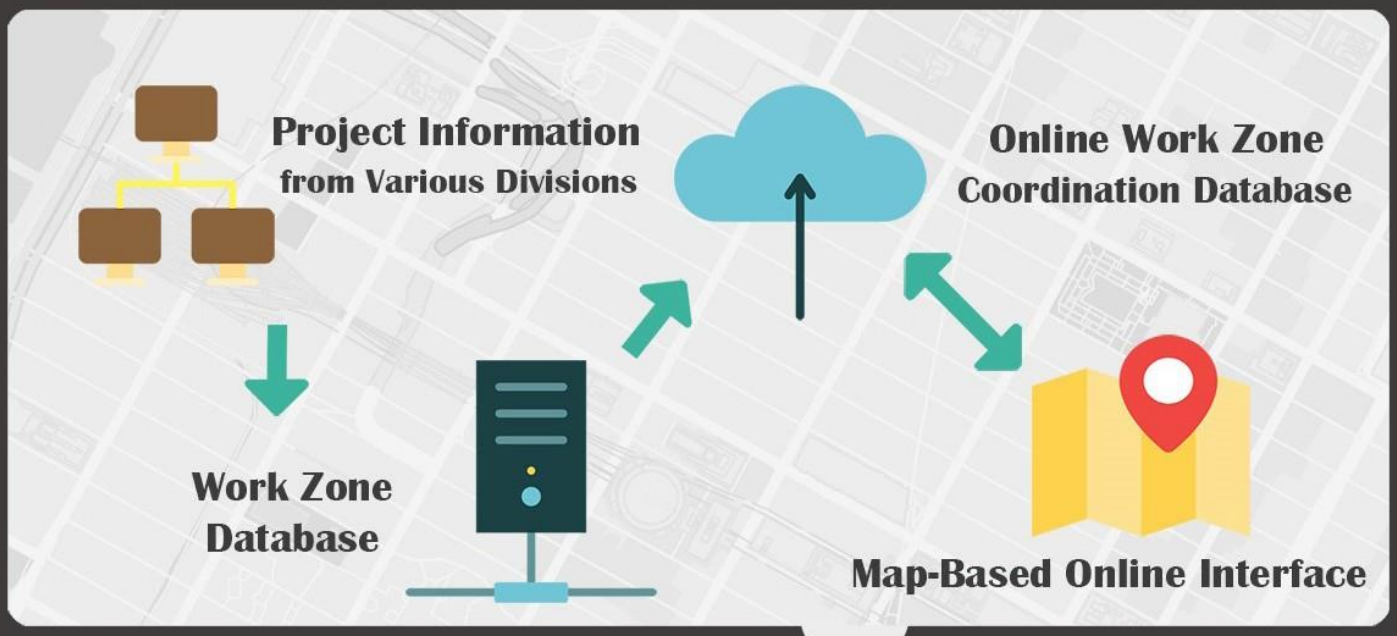
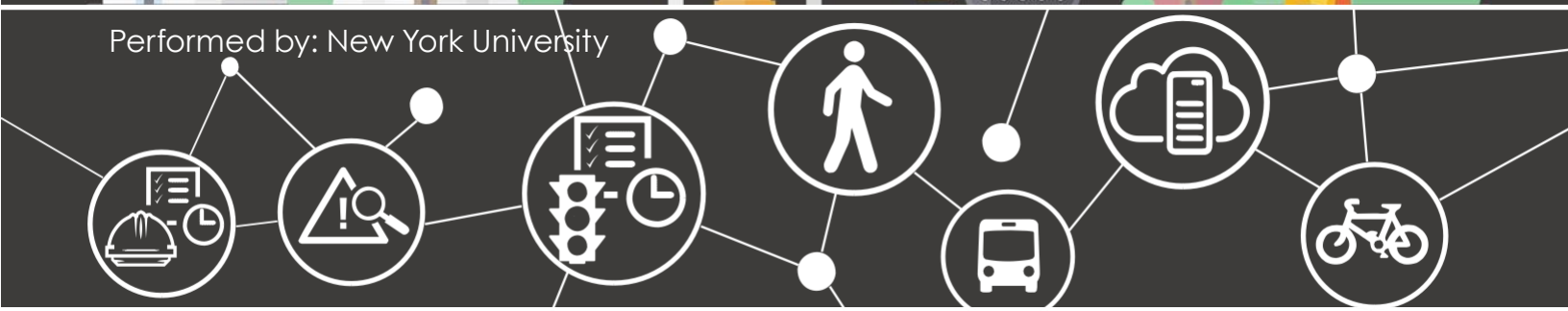
COORDINATED INTELLIGENT TRANSPORTATION SYSTEMS DEPLOYMENT IN NEW YORK CITY (CIDNY)

FINAL REPORT

Task 2 - Develop a Multi-agency / Multimodal Construction Management Tool to Enhance Coordination Projects City-wide During Planning and Operation Phases to Improve Highway Mobility and Drivers Experience



Performed by: New York University



U.S. Department of Transportation
Federal Highway Administration

NEW YORK STATE OF OPPORTUNITY. Department of Transportation

NEW YORK CITY DOT

University Transportation Research Center - Region 2

ABOUT THE PROGRAM

The FHWA, through its New York Division/New York City Metropolitan office is promoting programs pertaining to urban Intelligent Transportation Systems (ITS) in the region. The NYCDOT and NYSDOT-Region 11 Planning have taken the initiative in working with FHWA to take advantage of this FHWA program. NYCDOT and NYSDOT have developed the Training Courses and Research and Development Programs for the NYCDOT and NYSDOT Coordinated Intelligent Transportation Systems Deployment in New York City (CIDNY) which is a set of multi studies (task assignments) toward the fulfillment of the objectives of these programs.

The 2013 studies are being performed by institutions of the Region 2 University Transportation Research Center (UTRC). The studies focused on the following program areas: Construction Management, Traffic Demand Management, Dynamic Data Collection, Traffic Incident Management, Traffic Signal Timing and Detection Technologies, Strategic ITS Deployment Plan, Pedestrians and Cyclists Safety, Data Storage and Access Platform for MTA Bus Time Data.

The following tasks have been completed under this project.

- *Task 2 – Develop a multi-agency/multi modal construction management tool to enhance coordination of construction projects citywide during planning and operation phases to improve highway mobility and drivers experience*
- *Task 5 – Develop a Comprehensive Guide to Signal Timing, New Detection and Advanced Signal*
- *Task 6 – Strategic ITS Deployment Plan For New York City*
- *Task 7 – Research on Pedestrians and Cyclists Safety Using ITS Technology in NYC*
- *Task 8 – Develop Data Storage and Access Platform for MTA Bus Time Data.*

TASK 2 FINAL REPORT

UTRC-RF Project No: 57315-03-26

Project's Completion Date:
January 2017

Project Title: Develop a multi-agency/multi modal construction management tool to enhance coordination of construction projects citywide during planning and operation phases to improve highway mobility and drivers experience

Project's Website:
http://www.utrc2.org/research/projects

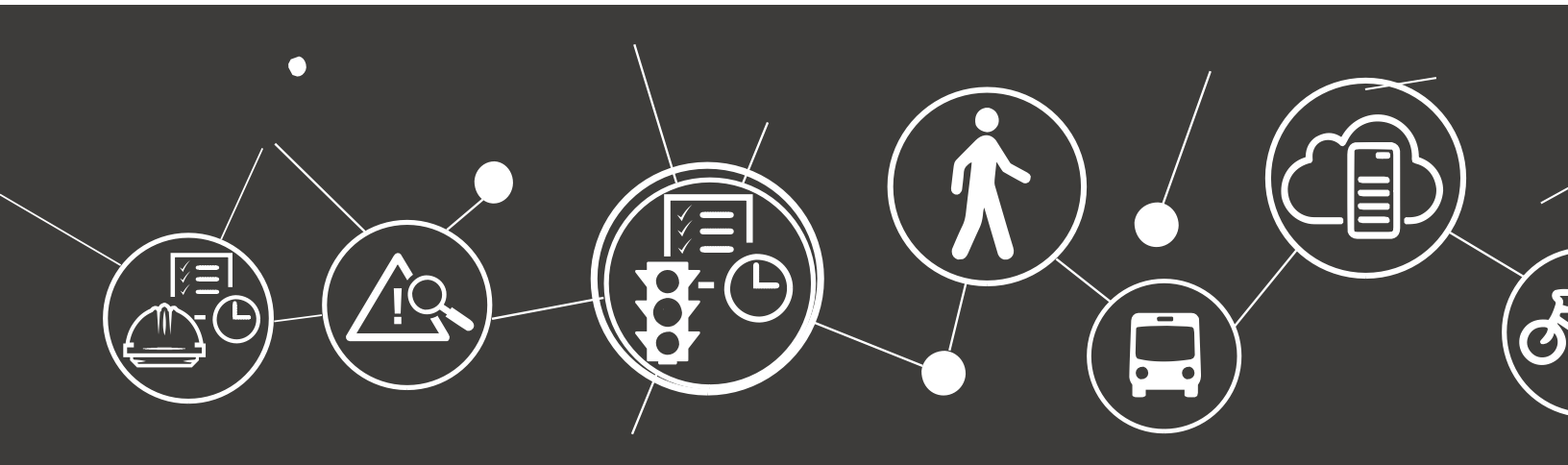
Principal Investigator(s):

Kaan Ozbay, Ph.D. Professor
Department of Civil and Urban Engineering & Center for Urban Science and Progress (CUSP)
Tandon School of Engineering, NYU

Camille Kamga, Ph.D. Director, UTRC
Assistant Professor
Department of Civil Engineering, CCNY

Performing Institution(s):

New York University (NYU)
The City College of New York, CUNY



1. Report No.	2.Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Develop a Multi-agency / Multimodal Construction Management Tool to Enhance Coordination Projects City-wide During Planning and Operation Phases to Improve Highway Mobility and Drivers Experience		5. Report Date January 30, 2017 6. Performing Organization Code
7. Author(s) Kaan Ozbay		8. Performing Organization Report No.
9. Performing Organization Name and Address NYU Tandon School of Engineering 6 MetroTech Center Brooklyn, NY 11201		10. Work Unit No. 11. Contract or Grant No. 57315-03, 04, 09-26
12. Sponsoring Agency Name and Address NYSDOT 50 Wolf Road Albany, New York 12232		13. Type of Report and Period Covered , Final, 4/24/15-10/31/16 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The main objective of this study is the assessment of the Construction Impact Analysis (CIA) and Work Zone Impact and Strategy Estimator (WISE) tools, and determining the feasibility of their customization with respect to New York City Department of Transportation (NYCDOT) and New York State Department of Transportation (NYSDOT)'s needs and requirements, cost of adoption and modification, and related issues. A comprehensive review of the current state of the practice in planning, coordinating and scheduling of work zone activities was conducted, and example tools and methodologies used by some state agencies were summarized. The research team also conducted an in-depth review of the two major computer tools developed for work zone coordination, the CIA tool by WSDOT and the WISE tool by the FHWA. The team identified the advantages and limitations of each tool and discussed the needs and requirements for NYCDOT/ NYSDOT for adopting these to be used in work zone coordination activities. Next, in-depth interviews with various transportation agencies were conducted to review the current state-of-practice related to work zones by each of these agencies. As part of this effort, the research team interviewed NYCDOT, TRANSCOM, Port Authority of New York and New Jersey (PANYNJ), Metropolitan Transit Authority (MTA) – New York City Transit (NYCT), New York City Department of Design and Construction (NYCDDC), New York State Department of Transportation (NYSDOT) and New York Metropolitan Transportation Council (NYMTC). The research team prepared ten general questions that were intended to identify the roles and responsibilities of various divisions within an agency and examples of work zone related activities with a focus on coordination, if any. In addition to the general questions, the team had also prepared several specific questions that focused on planning, operational and strategic aspects of work zones. The intent of these specific questions was to understand the agency specific policies followed to deal with reducing the impact of work zones via planning and intra and inter coordination and collaboration.

Based on the interviews conducted, it was understood that conflict analysis for work zones is often conducted for long-term projects, and a higher priority is given to capital projects that are at the regional level over short-term projects such as maintenance and utility work. Within NYCDOT / NYSDOT, this research project determined that the key issue that needs to be addressed is the lack of a unified and easily accessible database of the ongoing and scheduled work zones that is updated on a regular basis according to a predefined schedule. Based on the assessment of NYCDOT / NYSDOT's needs, it is determined that the identified parties within the NYCDOT/ NYSDOT and their counterparts outside the agency will benefit if they collaborate more closely and adopt a computerized tool that uses a unified database to coordinate of work zones. Based on the review of CIA and WISE computer tools, it was determined that neither one can address all the identified needs for coordinating work zones when multiple stakeholders and agencies are involved. Instead, a hybrid approach combining the best elements of each software tool along with some other reviewed tools seems to be the best approach for building a more comprehensive customized software for coordinating work zone schedules and conducting traffic analysis. The final report outlines this desired functionalities of the hybrid and customized to an ideal work zone coordination software tool.

17. Key Words Construction Impact Analysis, Work Zone Impact and Strategy Estimator, Construction Management	18. Distribution Statement

19. Security Classif (of this report)	20. Security Classif. (of this page)	21. No of Pages 90	22. Price
Unclassified	Unclassified		

CIDNY Task 2

Develop a Multi-agency / Multimodal Construction Management Tool to Enhance Coordination Projects City-wide During Planning and Operation Phases to Improve Highway Mobility and Drivers Experience

(Final Draft)

Submitted to:

New York City Department of Transportation

Prepared by:

UrbanITS CENTER FOR URBAN INTELLIGENT TRANSPORTATION SYSTEMS

UrbanITS is a sponsored research center in the Tandon School of Engineering of New York University. It is comprised of a number of faculty and researchers from several departments led by the Department of Civil & Urban Engineering. The mission of the center is to support and lead in research, education, and technology transfer of global state of the art engineering of transportation systems with an urban emphasis.

City Smart Lab is a multi-modal transportation infrastructure research and education laboratory under the UrbanITS umbrella

January 2017

Kaan Ozbay, Ph.D.
Professor
Department of Civil and Urban Engineering &
Center for Urban Science and Progress (CUSP)
Tandon School of Engineering
New York University
Director
C2SMART USDOT' Tier 1 University Transportation Center

Bekir Bartin, Ph.D.
Assistant Professor
Department of Civil Engineering,
Istanbul Kemerburgaz University

Jingqing Gao, MS
Graduate Research Assistant
Department of Civil and Urban Engineering
Tandon School of Engineering
New York University

Fernando Miguel Zingler, MS
Former Graduate Student
Department of Civil and Urban Engineering
Tandon School of Engineering
New York University

Camille Kamga
Director
Region-2 University Transportation Research Center
Assistant Professor
Department of Civil Engineering
The City College of New York

Dan Wan, MS
Research Assistant
Region-2 University Transportation Research Center

Sandeep Mudigonda, Ph.D.
Research Associate
Region-2 University Transportation Research Center

Table of Contents

List of Figures

List of Tables

INTRODUCTION

Background

Roadway work zones inconveniently affect the mobility and safety of travelers. A survey conducted by the Federal Highway Administration (FHWA) (1) showed that 32 percent of the respondents expressed dissatisfaction with work zones. In addition, work zone safety is a major problem. According to the latest statistics of National Highway Traffic Safety Administration (NHTSA), there were 669 work zone related fatalities in the U.S. in 2014. Although the number of work zone related accidents has decreased within the last decade, work zone safety is still a major problem in the U.S. (2)

The Final Rule on Work Zone Safety and Mobility (3) was published on September 2004, and applies to all states and local governments that receive Federal-aid highway funding, establishing, between other purposes, that these agencies are responsible for:

> *"Development and implementation of procedures to assess and manage work zone impacts on individual projects. This includes requirements for identifying significant projects and developing and implementing transportation management plans (TMPs). A significant project is defined in the rule as one that, alone or in combination with other concurrent projects nearby, is anticipated to cause sustained work zone impacts that are greater than what is considered tolerable based on state policy and/or engineering judgment."*

A TMP lays out a set of strategies for managing the impacts of a traffic work zone. The TMP requirement in the rule helps to expand mitigation of work zone impacts beyond traffic safety and control. The scope and content of the TMP required for a project are based on the agency's work zone policies, its understanding of the expected impacts of a work zone, and whether a project is classified to be significant.

With the growing number of work zones causing disruption to traffic, it is expected from these projects to fit into a budget, and be completed on time with satisfactory level of quality – what is popularly known as the "Project Management Triangle" (4). This scenario is rarely achieved in construction projects, because the presence of unexpected events that affects the planned completion of the work, requiring setting new goals and deadlines to revise the schedule of the project. This scenario is even more complicated to achieve when multiple projects occur that are close to each other at the same time.

Coordination of work zones must be done in order to maintain traffic flowing safely and with little inconvenience to road users. Coordination of work zones may include overlapping of different projects to avoid lane closures in the same area, coordination between parallel corridors, and complementary projects (such as utility work and surface

reconstruction). Time coordination of work zones that are in close proximity to each other requires careful planning since allowable lane closure times are usually limited. Challenges for transportation agencies are to effectively manage the impacts of work zones to relieve congestion and maintain the safety of drivers without having an affecting project schedules.

Coordinating roadway projects is not a new concept to many state department of transportation (DOT)s and local transportation agencies. Intra-agency communication and coordination practices are conducted by various states such as Utah DOT's I-15 Team and Traffic Management Committee, New York and New Jersey's TRANSCOM program, Gary/Chicago/Milwaukee Corridor Action Team Program that involve several DOTs and Toll Authorities, and Oregon DOT's Statewide Traffic Mobility Committee (5). These intra-agency communication practices aim at coordinating relatively long term and significant projects that have anticipated regional traffic impacts due to lane closures and detours.

As presented in detail in the State of Practice section of this report, there are several states that have been practicing corridor planning for coordinating short term and long term projects and streamlining project schedules to reduce the impact of work zones. In New York City, the Office of Construction Mitigation and Coordination (OCMC) of New York City Department of Transportation (NYCDOT) has been performing many of the above tasks for the last 50 years[1]. California Department of Transportation (Caltrans), Michigan DOT and Missouri DOT coordinate multiple maintenance, utility, surveying and construction projects within a corridor. There are also other states that coordinate short term and long term projects on parallel routes to minimize the region-wide impacts of work zones. Although New York City Department of Transportation and New York State DOT (NYSDOT) have been using state-of-the-practice techniques in coordinating and planning work zones, they can use some of lessons learned from the experiences of other States especially in terms of developing enhanced strategies of coordinating and planning projects of different scales, quantifying the impact of various combinations of proposed work zones within a corridor or in a specific region, and thus further reducing the negative impact of work zones.

Research Objective

The research team recognizes the fact that the key objective of this project is the assessment of the **Construction Impact Analysis (CIA)** and **Work Zone Impact and Strategy Estimator (WISE)** tools, and determining the feasibility of their customization with respect to NYCDOT's needs and requirements, cost of adoption and modification, and other issues.

[1] As per NYCDOT OCMC comments and feedback from the review meeting with NYCDOT on March 24th, 2017.

The current CIA tool as it is used by Washington State Department of Transportation (WSDOT) is specific to Washington State roadways and local roads, used to predict 'Hot Spots' where several construction sites are happening at the same time and coordinate conflicts between work zones. Therefore, as a first step, it is essential to determine the feasibility of customizing the tool for the NYC region. The WISE tool, on the other hand, is developed by FHWA to evaluate the impact of multiple "significant" projects that have been included in the Transportation Improvement Program (TIP). It is a decision tool for planners and engineers to estimate the impact of work zones and determine strategies to alleviate them.

It should be emphasized that there are many different types of work zones depending on the type of work, project duration, funding, etc. Before the CIA or WISE tools are customized for the NYC region, it is essential that the stakeholders within NYCDOT and NYSDOT be identified. This research project determines NYCDOT and NYSDOT units involved in work zone decision-making process, and identifies various types of projects that require short term or long term work zones.

In addition to the recurrent events, such as constructions and special events, NYCDOT is also interested in customizing these two tools for non-recurrent events, such as emergencies and incidents. It is important to communicate with the NYCDOT officials to clearly delineate the priority list of emergency events and the traffic management needs during these events. It is thus highly important that any new system also needs to be compatible with the latest version of the city planning map, to ensure future coordination with Office of Emergency Management, Police Department, Fire Department, and other emergency services, and to track emergency closures. A live spatial mapping capability for each location to allow automatic interaction with legal permit data tracking and various activities at other construction sites can be a useful feature of a future tool[2].

Finally, the research team recognizes the importance of a roadmap on how to utilize these tools within NYCDOT protocols and regulations. Therefore, this research project presents guidelines and recommendations on how these two tools or any other candidate software tools should be used during recurrent operations and non-recurrent events.

LITERATURE REVIEW

A well-planned strategy for maintaining traffic flow and ensuring the safety of motorists and workers is an essential part of work zone management. FHWA work zone mobility and safety rule requires state and local transportation agencies that receive federal

[2] As per NYCDOT OCMC comments and feedback from the review meeting with NYCDOT on March 24th, 2017.

funding to develop a TMP to manage the safety and mobility of work zones for significant projects (3). Whether it is a short- or long-term project, estimating the extent of work zone impact on mobility is a crucial part of a TMP. Also knowing whether the proposed work zone configuration will cause queues and delays that exceed allowable thresholds will enable practitioners to determine other project alternatives and mitigation strategies.

State DOTs have been using various analytical tools to estimate traffic delays due to work zones. Most of these agencies have set delay thresholds that help them determine the duration of lane closures to minimize traffic disruption. Several tools are available for estimating the effects of various transportation projects. These tools vary in level of complexity, and each tool offers different capabilities. Some tools were designed specifically for work zone applications, while other traffic analysis tools, although not designed specifically for work zones, can be used to analyze work zone situations.

Several Department of Transportation (DOT) offices adopt spreadsheet-based tools for estimating the impacts of work zones. The spreadsheets estimate delay and queue lengths as the main output values using the graphical procedures explained in the Highway Capacity Manual (HCM). Calculations are usually carried out in Microsoft® Excel. These tools require very few inputs and give quick results. The accuracy of delay and queue estimation of these tools depends highly on the capacity assumptions and the accuracy of hourly volume data.

Although delay is a fundamental concern, other factors have significant impact on the work zone planning, such as budget, strategic planning, logistics of supplemental material, coordination among agencies and contracting third-parties.

The following subsections detail the current practice of scheduling work zones and estimating the impact of work zones on traffic.

Scheduling and Operations

Developing and managing a roadway construction project is very challenging for transportation agencies and state DOTs since there usually is a multitude of stakeholders involved in the decision-making process. The impact of a work zone is even more far-reaching for projects located in urban areas, where roadway construction projects can cause higher delays and cause inconvenience for pedestrians and residents. Several studies have been done on creating models to optimize the scheduling of work zones, and most of them combine some simulation tool with an algorithm that can produce a sequence of projects to be realized over time.

The schedule of a work zone must define each involved project and how they will be executed, monitored and controlled. Ideally, it should contain all the information of the project(s) in an integrated and efficient environment, contributing to the dissemination of the information among all the stakeholders. The schedule is an output of the information

provided by the project initiators or sponsors, used by project manager with the authority to apply organizational resources to projects activities. It documents information such as business needs, assumptions, constraints, the understanding of customer's needs and high level-requirements, and result expected.

Sukumaran (6) developed a stochastic model to analyze the factors affecting a construction schedule in highway work zones and to determine probable changes, and a detailed application of the 4-level framework of the model presented through three case studies from Indiana Department of Transportation (INDOT). The model includes a methodology to calculate Daily Road User Costs which are used to assist in the planning process. The results help to prioritize tasks and schedule work zone activities based on the expected traffic delay during construction.

Lee (7) proposed a model based on the route-changing behavior of road users that tries to minimize the total traffic delay due to work zone. The model was created in VISSIM for traffic assignments and proposes the best scheduling using colony optimization to search the near-optimal schedule.

Bayraktar (8) evaluated the trade-offs between different parameters such as costs, quality, public safety and others, among different strategies that can be implemented by agencies. The study explained the dynamic relationship between different stakeholders in a highway work zone project. The influence of each stakeholder is investigated for the parameters used in modelling the contracted schedule.

Ma (9) proposed a hybrid genetic algorithm to generate a lane closure schedule with a simulation package that calculates the total travel time under various scenarios. As a widely used methodology, use of a genetic algorithm was claimed to be an effective optimization tool for scheduling lane closures.

The Project Management Book of Knowledge (4) provides guidance on documentation and presents the best practices in creating a schedule model for work zone projects (See Figure 1). The project requirements include; full detailed characteristics of a work zone, information on the responsible staff, project duration, resources, severity, costs and location. In addition, the constraints of a project such as budgets, available teams and contractors, impact on the network, priorities, are used as inputs for the schedule management process that defines the sequence of projects.

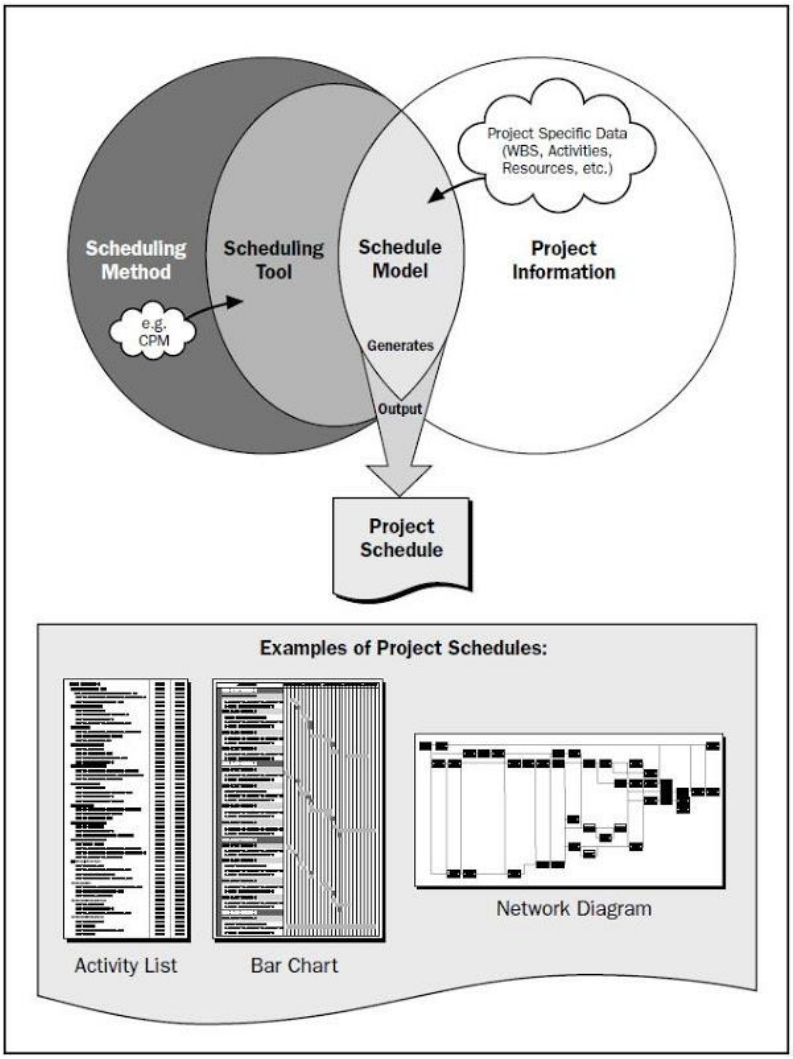


Figure 1: Project Schedule Methodology (4)

Traffic Impact Analysis

Conducting a traffic analysis before the implementation of a work zone is necessary to understand its impact. A work zone can affect the road capacity as it requires lane closure(s), and if the traffic volume exceeds the remaining roadway capacity, congestion occurs, leading to vehicular queues and delays. The additional time needed for vehicles to traverse the same length of roadway when there is a work zone can be referred as a traffic delay caused by the work zone. Moreover, because of the stochastic nature of flow, queues may form at a work zone even if the traffic flow falls below capacity. The traffic impact analysis may necessitate a specific software or traffic simulation in more complex cases, but generally can be done only using criteria defined by the agencies that simplify the understanding of the work zone's requirements. There are various methodologies that

can be used to estimate the queue length and delay due to a work zone. Generally, two types of queuing analyses are used to analyze the formation and dissipation of queues: 1) Deterministic queuing analysis, in which the arrivals of the vehicles are assumed to follow a uniform pattern, and 2) Stochastic queuing analysis where the distribution of the vehicle arrivals follows a probability distribution. Some crude assumptions are taken into account in order to simplify stochastic analyses.

The following subsections describe each queuing analysis approach.

Deterministic Queuing Analysis

Deterministic queuing analysis can be carried out at a macroscopic or microscopic level. While macroscopic traffic models focus on trying to explain the relationships among traffic characteristics such as flow and density, microscopic traffic models focus on single vehicle-driver units. Service time rates and the arrival of vehicles are considered continuous at the macroscopic level. For the microscopic level, both service time rates and the arrival of vehicles are assumed to be discrete.

A deterministic macroscopic queuing model is built on the conversation of flow principle. Conversation of flow theory proposes that the number of vehicles entering a specific part of a roadway at a particular period of time must equal the number of exiting vehicles at the same time period under homogeneous roadway conditions. When there exists a work zone on the freeway acting as a bottleneck, the number of exiting vehicles may be lower than the entering vehicles. The difference refers to a queue that has formed upstream. The analysis simply treats the length of the queue as the difference between the arrivals and departures at a specific point.

Cassidy and Han (10) estimated the average delay initiated by work zones on a two-lane two-way highway with one lane closure. They stated that a number of different factors influence delay, and that these factors should be kept within acceptable ranges. One of the most important factors in their model was the length of the work-zone. According to this study, delays incurred by motorists can be reduced or increased by changing the length of the work-zone. They estimated delays and queue lengths as a function of work-zone length; if this length is fixed, this method can be used to determine unacceptable levels of delays during the day. The model is also able to institute suitable green times and cycle lengths when there was a signal control on work-zone entrances. Their procedure estimates delay by estimating the right-of-way times in each cycle that takes place in a given time interval. When they predicted green times, they used deterministic queuing techniques to estimate delays. This method is more applicable to work-zone locations in which traffic demands constitute under saturated conditions.

Jiang (11) developed a model to estimate delays in which the work zone related delays were grouped under several different categories: vehicle deceleration prior to entering work zones, moving delays experienced by vehicles passing through work zones at lower

speeds, acceleration delays experienced by vehicles accelerating after existing work zones, and queuing delays caused by the ratio of vehicle arrival to discharge rates. The developed model uses the vehicle queue-discharge rates to estimate traffic delays instead of the work zone capacity. According to this methodology, the total traffic delay at a work zone can be calculated with the following formula:

$$DELAY_I = F_{aI}\,[d_d + d_z + d_a + (1 - t_I)d_w] + D_I \quad (1)$$

Where,

F_{aI} = hourly volume of arrival vehicles at hour i
d_d = delay due to vehicle deceleration before entering work zone
d_z = delay due to reduced speed through work zone
d_a = delay due for resuming freeway speed after exiting work zone
d_w = delay due to vehicle queues during uncongested traffic
D_I = delay due to vehicle queues during congested traffic

Chien and Schonfel (12) proposed a modeling approach that determines how work zone lengths can be adjusted based on factors such as vehicle speeds and approaching traffic flow. They used deterministic queueing analysis in their study, and found that their method provides a useful approach for decreasing both traffic delays and costs. Because the user delay is represented as a constant average cost per vehicle hour, the delay in the model for each vehicle is assumed to be proportional to the time of the delay. The queue delay in the model is formulated as:

$$C_q = \frac{v_d}{2L}\left(1 + \frac{Q - c_w}{c_0 - Q}\right)(Q - c_w)(z_3 + z_4 L)^2 \quad (2)$$

Where,

C_q = the queue delay cost per maintained kilometer
c_w = the zone capacity
c_0 = roadway capacity in normal conditions
v_d = the average delay cost
Q = approaching traffic flow
z_3 = the setup time
z_4 = the additional time required per work zone kilometer
L = the work zone length

Jiang and Adeli (13) also used a deterministic queuing model for both short term and long term work zones based on the average hourly traffic flow. Their estimated delay time consists of the upstream queue delay time (t_q), and the moving delay time (t_m) through the work space.

$$t_d = t_q + t_m \quad (3)$$

$$t_q = \sum_{t=t_i}^{t_i+D-1}\left(\frac{T_t + T_{t+\Delta t}}{2}\Delta_t\right) \quad (4)$$

$$t_m = \sum_{t=t_i}^{t_i+D-1} \Delta t_m \quad (5)$$

Where,
t_i = the starting time at the work zone in hours ranging from 1 to 24,
D = the time period required to complete the maintenance for the work zone,
Δt = the given time period,
T = the cumulative number of vehicles,
Δt_m = the moving delay time.

Stochastic Queuing Analysis

Stochastic queuing analysis methods are relatively harder to apply because of the randomness and the uncertainty in traffic flow. Therefore, in order to use these methods, several simplifications are applied to the models. Two of the more common assumptions used to simplify stochastic models are 1) the arrival of vehicles follows the Poisson process and 2) the mean arrival flow rate is constant. The stochastic queuing analysis tries to estimate the delay experienced by vehicles at a bottleneck, such as those found at a work zone, by defining the statistical distributions of queue lengths and delays. This analysis is also used for both under saturated and saturated traffic conditions. The degree of saturation is determined by an intensity equivalent to the volume to capacity ratio.

$$\rho = \frac{\lambda}{\mu} \quad (6)$$

Where,
ρ = traffic intensity,
λ = mean vehicle arrival rate,
μ = mean vehicle service rate.

If the traffic intensity is less than one, then the traffic conditions are under saturated. Likewise, if the intensity is greater than one, then there is no mathematical solution to above formulation. In order to estimate the delay experienced by motorists, the queuing process should be converted into a deterministic queuing problem by using several time slices with different mean arrivals and service times.

Chitturi et al. (14) proposed a methodology to estimate capacity, queue length, and delay for stopped queues at work zones. They estimated the total delay experienced by users by adding up the delay time due to queuing and the delay time due to slower speeds. Delay calculation is performed using several steps including estimation of speed and capacity reduction. As a final output, this model calculates user costs. Although there were some adjustment factors that were both taken directly from the highway capacity manual (HCM), which are not necessarily given for work zones, there was a close similarity between the estimated results and the field data.

Ramezani et al. (15) calculated total delay at work zones. First, they determined the number of vehicles moving in the queue and then they found the length of the queue and

the speed. From these variables they found travel times and used them to compute the delay. Ramezani and Benehokal (16) later proposed a methodology to estimate queue length and delay. In their model, it is assumed that throughout the work space and/or the transition area there may be more than one bottleneck found within the work zones. Their methodology utilizes speed-flow curves of the bottlenecks, the relationship between demand and capacities, and initial queue conditions. When the volume exceeds the transition area and the work zone capacity, there will be active bottlenecks at both locations. Likewise, if the approaching volume stays the same or reaches to a higher level, the end of the queue will reach the transition area and they will be dependent to one another. Therefore, the bottleneck in the transition area will be neutralized and only remaining active bottleneck will be the one in work zone. If the volume is less than the capacity, again the work zone will be the only active bottleneck. They estimated queue length at the end of each minute using shockwave theory, and then they computed shockwave speed. It was assumed that the vehicle speeds upstream of the queue are the same as the free flow speeds. Arriving volume and shockwave speed are measured every other minute. They multiplied shockwave speed with the interval length and the previous interval's estimated queue length. Finally, in order to find stable estimation of queue lengths, they used the moving average method.

Ullman and Dudek (17) developed a theoretical approach for estimating queue length during short-term roadwork on urban freeways. They argued that although traditional approaches such as macroscopic work zone analysis tools work well for rural and suburban work zones, they may highly overestimate traffic queues. This overestimation is mainly due to entrance and exit ramps being spaced relatively far apart whereas in urban areas the ramps are closely spaced, which enable users to choose other alternative routes. Their model is based on macroscopic fluid-flow analogies of traffic and considerations of the freeway corridor as a section of permeable pipe. This model was also calibrated to represent the magnitude of traffic queues at work zones on freeways in Texas. They used macroscopic fluid-flow theory to examine the diversion under lane closures using historical data. The method required extensive inputs to estimate the corridor permeability factor relating to the diversion potential of roadway segments. They used Darcy's Law to represent the relationship between traffic queuing and diversion.

$$q_{side(1)} = KiA = K' \frac{\Delta \overline{p_1}}{TE} \Delta x_i \qquad (7)$$

Where,

$q_{side(1)}$ = the flow permeating out the sides of the pipe through each segment (VPH)

Δp_1 = the average traffic stream pressure differential between roadway and the rest of the corridor within Δx_1

A = area through which flow is occurring

K = coefficient of permeability

TE = total energy of the traffic stream, and

i = energy gradient across the permeable medium

With the help of the hydrodynamic analogy, a shockwave is assumed to form when traffic streams of varying stream conditions exist. Cumulative plots are used as the graphical interpretations of the function that represents the cumulative number of vehicles which pass an observer at a specific time interval, t. These plots are used to examine the flow of vehicles that pass a number of bottlenecks. The transition of two traffic moving stages creates clear disruptions in this plots that can easily be identified and the propagation can be measured over time. Newel (18), for instance, used these plots as an examination tool.

Many researchers have used the analogy of fluid dynamics to characterize traffic flow. Lighthill and Whitham (19) were the first researchers who tried aforementioned analogy in transportation. They analyzed the existence of shock-waves and traffic, and their theory demonstrated that one dimensional waves can be applied to transportation in order to estimate the highway traffic flow behavior.

Figure 2 shows a traffic stream that is moving on a roadway at a given flow, speed, and density. If it is assumed that a truck comes into the stream and slows down the flowing traffic, the effect of this behavior can be explained by using shock-wave theory. The vehicles that are in the platoon will adjust their spacing as shown in Figure 3. Given conditions, the speed of the shockwave between two conditions are given by

$$w_{AB} = \frac{q_B - q_A}{k_B - k_A} \quad (8)$$

In more general form:

$$q_i = k_j - k_i \quad (9)$$

$$w_{ij} = \frac{q_j - q_i}{k_j - k_i} \quad (10)$$

Where,
w: Speed of the shockwave (MPH)
q: Flow (VPH)
k: Density (VPM)

The first equation above demonstrates the relationship between flow, density, and speed. The second equation defines the speed at the change of traffic conditions, analogous to a shock-wave which propagates along a roadway. Figure 2 shows that the shock waves produced at point B are propagated in the backward direction. These two equations basically represent their model.

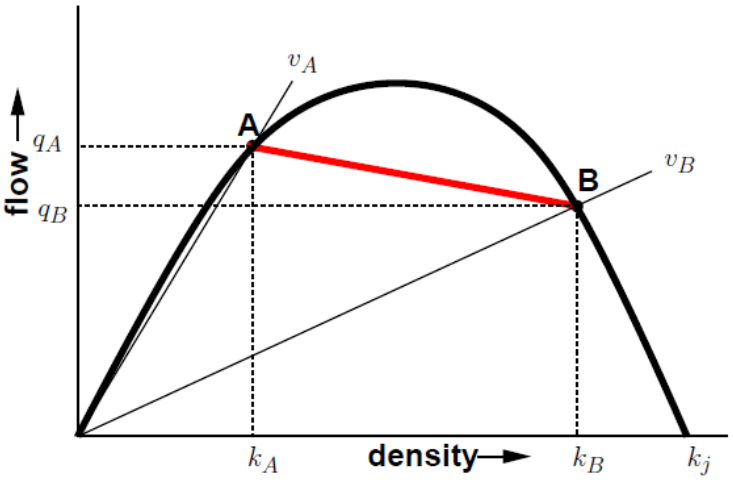


Figure 2: Shock Wave Flow-Density Curve

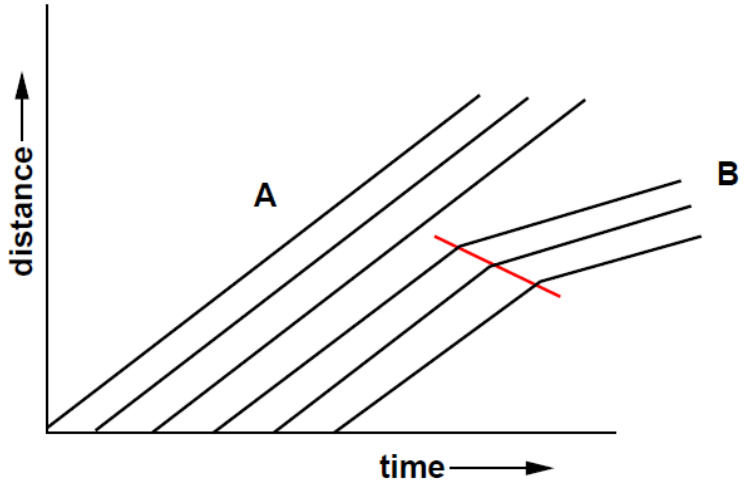


Figure 3: Shock Wave Time-Space Diagram

The major difference between the shock-wave and deterministic queuing models is that they use different methods to explain vehicles that are queued upstream of a bottleneck. Shockwave analysis studies the spatial dimension of queues. Therefore, shock-wave analysis captures more realistic behavior of queues and it determines the maximum queue reach.

State-of-the Practice

This section describes the current state of the practice of coordinating work zones, adopted from agencies in the U.S. National Cooperative Highway Research Program (NCHRP), which lists various strategies for transportation agencies to improve

coordination, planning and scheduling of work zone activities. Coordination may involve county and local highway agencies and contractors as well as highway agency personnel representing different divisions such as maintenance, construction, design and surveying, traffic operations. Some of the strategies recommended in the NCHRP report are (20):

- Coordinating activities so that they can be scheduled to overlap, or not overlap, as appropriate.
- Work zones on two parallel corridors can reduce the alternative route choices for travelers, which could increase congestion caused by work zones. Such projects need to be scheduled at different times.
- Separate projects on the same route (resurfacing, surveying, and utility) should be scheduled to occur at the same time or as close together as possible to minimize disruption to traffic and to take advantage of the already deployed work zone traffic control.

Coordinating work zone activities and improving communication among agencies have already been practiced by various State DOTs. Next, example tools and methodologies used by some state agencies will be discussed.

Oregon Department of Transportation Region Mobility Schedule

The Oregon Transportation Investment Acts (OTIA) was passed in 2001 and 2002 and dedicated $2.5 billion over a 10-year period to upgrade Oregon's highways, interchanges, and bridges. With more than 100 active work zones to manage during each summer period, ODOT created a Statewide Traffic Mobility Manager and Mobility Operations Center. The purpose of the Center is to monitor congestion due to active work zones and coordinate the work zone lane closures to reduce delays. (21)

All project schedules are loaded into a common project database by each area from a spreadsheet. Project schedules and mobility impacts are then evaluated by the Mobility Operations Center, which has the authority to reschedule of work zone activities if acceptable delay thresholds are exceeded. However, this analysis is not conducted by the software itself since it does not have the capability of providing traffic impact analysis (21).

The ODOT coordinates projects on different corridors by using a "Region Mobility Schedule" to see conflicts between the work affecting critical route pairs and coordinated activities. Figure 4 shows a snapshot of the Region Mobility Schedule spreadsheet.

The tool uses a GIS interface to coordinate the network system that displays information about the network design, mileposts, and projects characteristics (See Figure 5).

Region Mobility Schedule

ID	Key No.	Contract No.	Task Name	Mile Post Begin	Mile Post End	PM	Start	Finish
1	**2**	**0**	**I-5 Projects**	**283.21**	**306.73**		**Thu 5/6/10**	**Fri 6/28/13**
2	14949	14225	I-5: Iowa Viaduct	298.09	298.39	Statler	Thu 5/6/10	Fri 6/28/13
3	15140	14304	I-5: Holladay-Marquam & I-405: Fremont Bridge	300.92	301.98	Beeson	Thu 2/10/11	Thu 9/27/12
4								
5	**6**	**0**	**I-84 Projects**	**5.5**	**82.08**		**Wed 2/24/10**	**Mon 11/30/15**
6	14032	14165	Bundle 210 - Sandy River Bridge EB/WB	17.68	17.68	OBDP - Barnha	Wed 2/24/10	Fri 11/29/13
7	11017	14401	HCRH State Trail: JB Yeon - Moffett Creek	37.52	39.02	Beeson	Thu 10/27/11	Fri 10/18/13
8	17168	0	I-84: Bridge Deck Overlays	35.06	42.05	Beeson	Thu 10/18/12	Mon 9/30/13
9	16267	0	I-84: MLK Blvd. - I205	0.40	5.60	Earlywine	Thu 11/8/12	Fri 5/31/13
10	16846	0	I-84 EB to I-205 NB Aux Lane	5.5	6.6	Frietag	Thu 3/7/13	Wed 5/28/14
11	17541	0	I-84 at Troutdale Interchange	16.58	17.35	Beeson	Thu 11/14/13	Mon 11/30/15
12								
13	**6**	**0**	**US26 (East) Projects (Route Exceptions Req'd)**	**3.52**	**40.01**		**Thu 10/6/11**	**Thu 8/22/13**
14	17483	14393	US26: MP 22.5 - Luzon Ln.	22.5	26.33	Beeson	Thu 10/6/11	Thu 10/11/12
15	13717	0	US26: MP 49.60 - MP 50.00 (Rockfall)	49.20	50.00	Statler	Thu 5/10/12	Wed 11/28/12
16	15051	0	US26: SE 122nd - SE 136th	7.21	7.0	Beeson	Thu 7/26/12	Tue 11/13/12
17	15773	0	US26: Springwater Intersection	16.24	16.24	Beeson	Thu 11/1/12	Wed 7/31/13
18	1504713717	0	US26: MP 49.20 - MP 57.45 (Pavement Preservation)	49.20	57.45		Thu 8/22/13	Thu 8/22/13
19	15052/13717	0	US26: MP 49.20 - MP 51.00 (Downhill passing lane/mec	49.20	51.00		Thu 8/22/13	Thu 8/22/13
20								
21	**7**	**0**	**US26 (West) Projects**	**24.13**	**67.0**		**Wed 5/12/10**	**Wed 12/31/14**
22	14070	14228	US26: 185th - Cornell Rd.	64.30	67.0	Larson	Wed 5/12/10	Thu 6/28/12
23	16141	14429	US26: Sylvan - I405	71.53	73.94	Statler	Thu 3/29/12	Fri 5/31/13
24	14838	14459	US26: West Fork Dairy Creek Bridge #02673	46.2	46.4	Larson	Thu 5/17/12	Wed 7/11/12
25	16842	0	US26: Shute Interchange	61.07	61.07	Larson	Thu 3/8/12	Thu 12/26/13
26	12885	0	US26: Glencoe Road Interchange	56.94	57.22	Larson	Thu 4/12/12	Wed 12/31/14
27	17991	0	US26 (SW Kelly Ave): Ross Island Br - OR99W (Naito Pl	0	0.31	Earlywine	Tue 10/16/12	Fri 6/28/13
28	16137	0	US26: Jefferson St - Highland Interchange	73.12	73.31	Statler	Thu 3/28/13	Thu 10/31/13
29								
30	**2**	**0**	**I-205 Projects**	**0**	**27.18**		**Thu 2/9/12**	**Mon 4/28/14**
31	16847	14417	I-205: SE Foster Rd - SE 82nd Drive	15.87	17.80	Earlywine	Thu 2/9/12	Wed 10/31/12
32	14856	0	I-205 @ NE Airport Way Interchange	24.65	24.65	Freitag	Thu 7/18/13	Mon 4/28/14
33								
34	**1**	**0**	**US30 (East) Projects**	**9.0**	**13.0**		**Thu 5/24/12**	**Thu 10/31/13**
35	15068	14471	US30B: NE 122nd Ave. - MP 13.54	12.0	13.0	Beeson	Thu 5/24/12	Thu 10/31/13
36								
37	**4**	**0**	**US30 (West) Projects**	**1.93**	**69.95**		**Thu 1/6/11**	**Mon 9/30/13**
38		0	Lewis and Clark (Longview) Bridge	48.68	48.68	OR/WASH	Thu 1/6/11	Fri 1/4/13
39	11196	0	US30: "B" Street Bike/Ped Path	46.62	47.34	Weatherford	Thu 3/22/12	Wed 12/26/12
40	16151	0	Lower Columbia River @ Cornelius Pass Rd.	13.05	13.32	Larson	Thu 8/9/12	Wed 7/31/13
41	17566	0	US30: McNamee Rd. - MP 17.93	13.03	17.93	Larson	Thu 9/13/12	Mon 9/30/13
42								
43	**6**	**0**	**OR99 (West) Projects**	**7.0**	**10.8**		**Thu 1/6/11**	**Tue 12/31/13**

Page 1

Tue 9/18/12

Figure 4: ODOT Region Mobility Schedule (22)

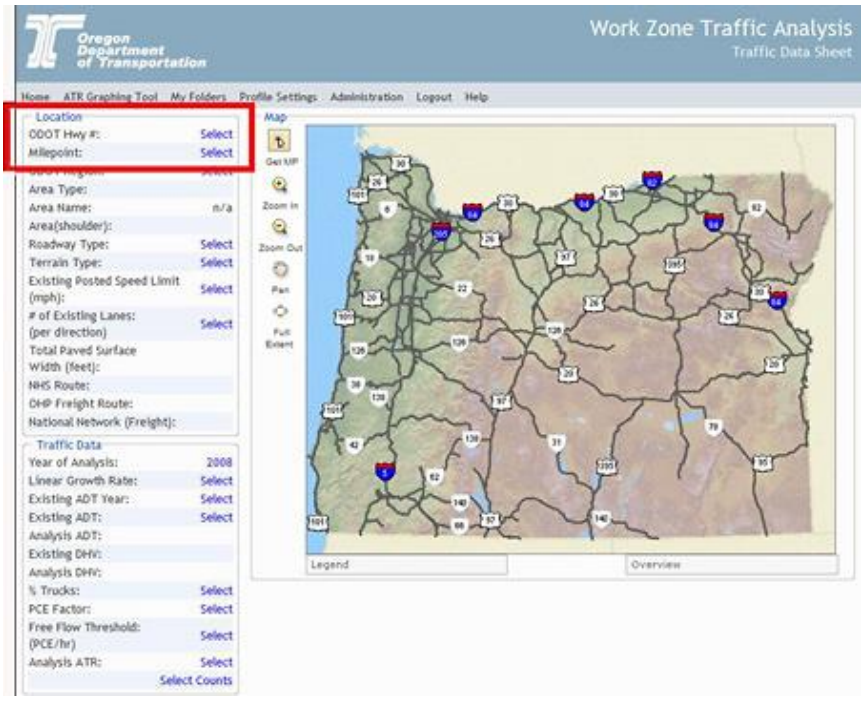


Figure 5: ODOT Region 1 and 2 Coordination (21)

Great Lakes Regional Transportation Operations Coalition (GLRTOC)

The Great Lakes Regional Transportation Operations Coalition (GLRTOC) includes different agencies that extend from Minnesota through Wisconsin, Illinois, Indiana, Michigan, and Ontario (23). They hold an annual work zone preview during the first week of February in Chicago, where the planned work zones are shared between the member agencies. With the vast amount of data being shared, it was seen that need for a map on which all the work zones could be placed with detailed information. Given that the objective was to improve coordination across agencies, they needed to be able to visually see where conflicts or opportunities existed. Figure 6 shows a sample from the GLRTOC visual work zone review.

The key elements of their work zone efforts are an annual work zone preview, an online map, and corridor performance monitoring. In 2012, GLRTOC was awarded funds through the USDOT Multi-State Corridor Operations and Management to improve center-to-center communications and expand traveler information services across the region, and for additional work zone collaboration, coordination, and monitoring. The work zone effort entails: 1) resource support for the annual work zone preview; 2) major changes to the work zone mapping application; and 3) multiagency work zone performance monitoring.

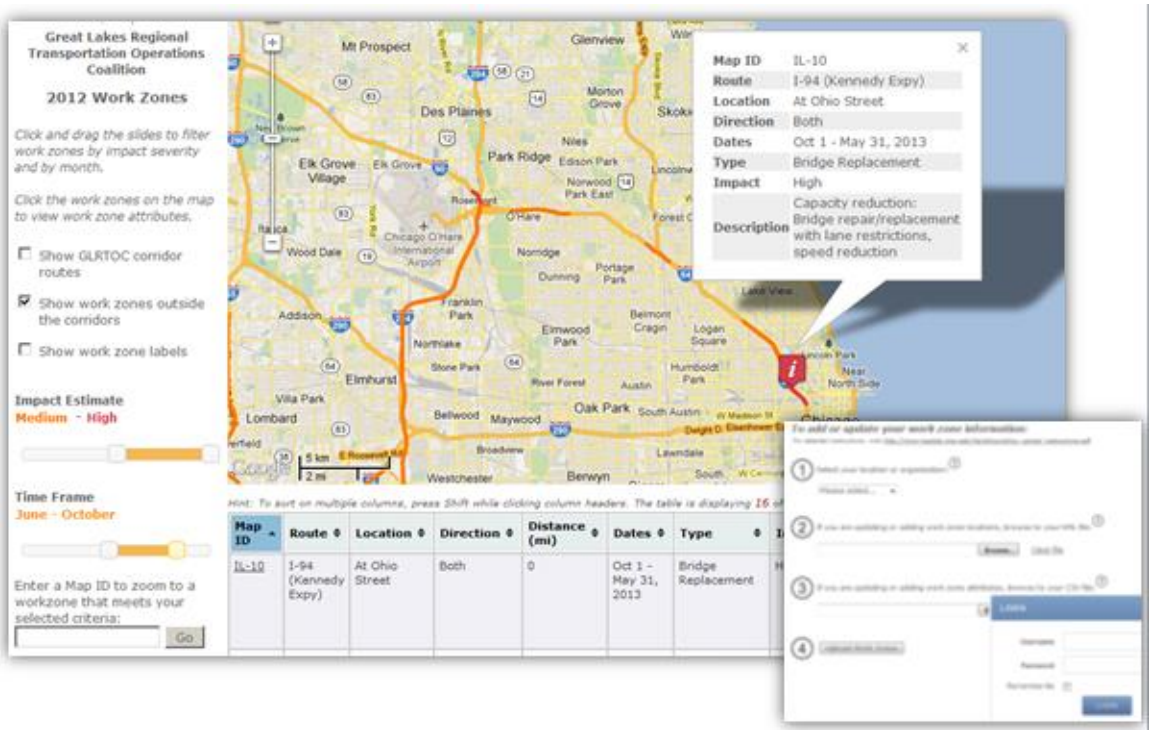


Figure 6: Work Zone Details on GLRTOC (23)

GLRTOC provides an online work zone map, displaying all planned work zones in the region (See Figure 7). This map is developed by collecting information from all member agencies in any format they already had it available and then creating the map using manual processes and ArcGIS. GLRTOC is enhancing the map to provide for multi-user, authenticated editing where users who are logged in across any agency will be able to modify, add, or remove work zones throughout the year. In addition, public users will be able to search, query or extract work zone information directly from the online map interface.

GLRTOC is working to improve multi-agency work zone performance monitoring via a pilot test on the I-39/90 segment between Madison, WI and Rockford, IL. This 65-mile segment is mostly rural and has little or no traffic detection, but is a key recreational and freight corridor maintained by three different agencies: Wisconsin DOT, Illinois DOT, and Illinois tollway.

The information, such as travel times, will also be publicly available online, with text messages, and dynamic messages. This information will be also stored for researchers.

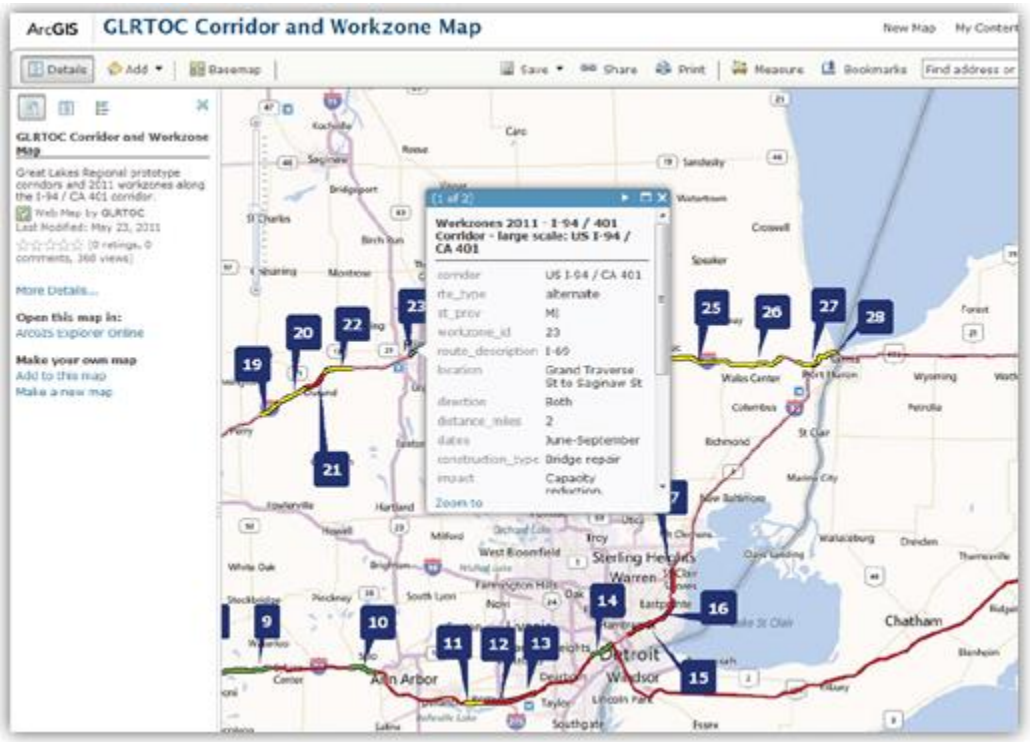


Figure 7: GLRTOC Corridor and Work Zone Map (23)

Caltrans LCS Web-based Lane Closure System

Caltrans coordinates multiple construction and maintenance projects within a highway corridor. Caltrans develops a single corridor or regional TMP when multiple projects are in the same corridor or on corridors within the same traffic area. The TMP Manager coordinates the development and implementation of corridor and regional TMPs. The TMP team includes representatives from the Department's Divisions of Construction, Maintenance, Project Management, and Traffic Operations for each of the affected Districts and local law enforcement, transit, and emergency services agencies. They use a web-based lane closure system (LCS) to perform several tasks. LCS allows decision-makers to review the details of a lane closure request, to check for potential conflicts, to approve or reject requests, to ensure that the closure is consistent with any corridor TMPs, and to monitor closure progress. **Figure 8** shows a snapshot for the Caltrans web-based LCS system.

As an example of the Caltrans work zone consolidations strategy, a 10-mile stretch of I-405 and 4 miles of the southbound lanes were closed for 53 hours, from July 15 to July 17, 2011. The closure enabled workers to demolish half of the Mulholland Drive Bridge so they could widen the expressway between the Westside and the San Fernando Valley. For the weekend of September 29th, 2012, the same stretch of I-405 was fully closed so workers could demolish the northern side of the bridge during phase 2. Multiple divisions (maintenance, utility, survey, and others) worked on the closed 10-mile section of highway. **Figure 9Figure 8** shows the full lane closure for both ways during the Mulholland Drive Bridge construction.

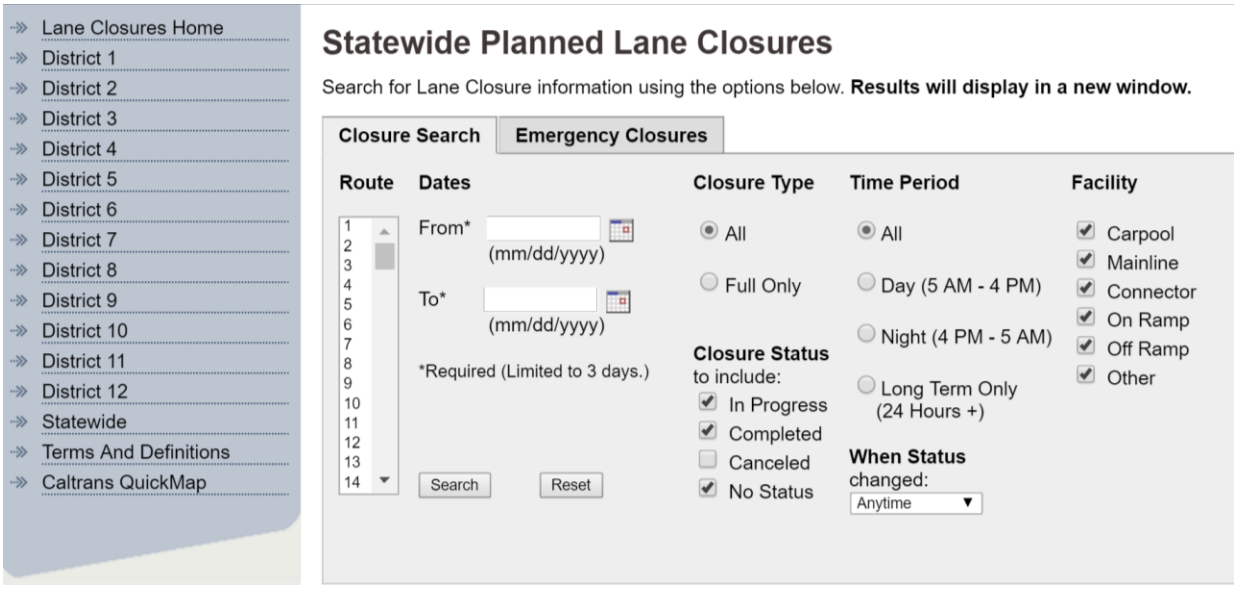
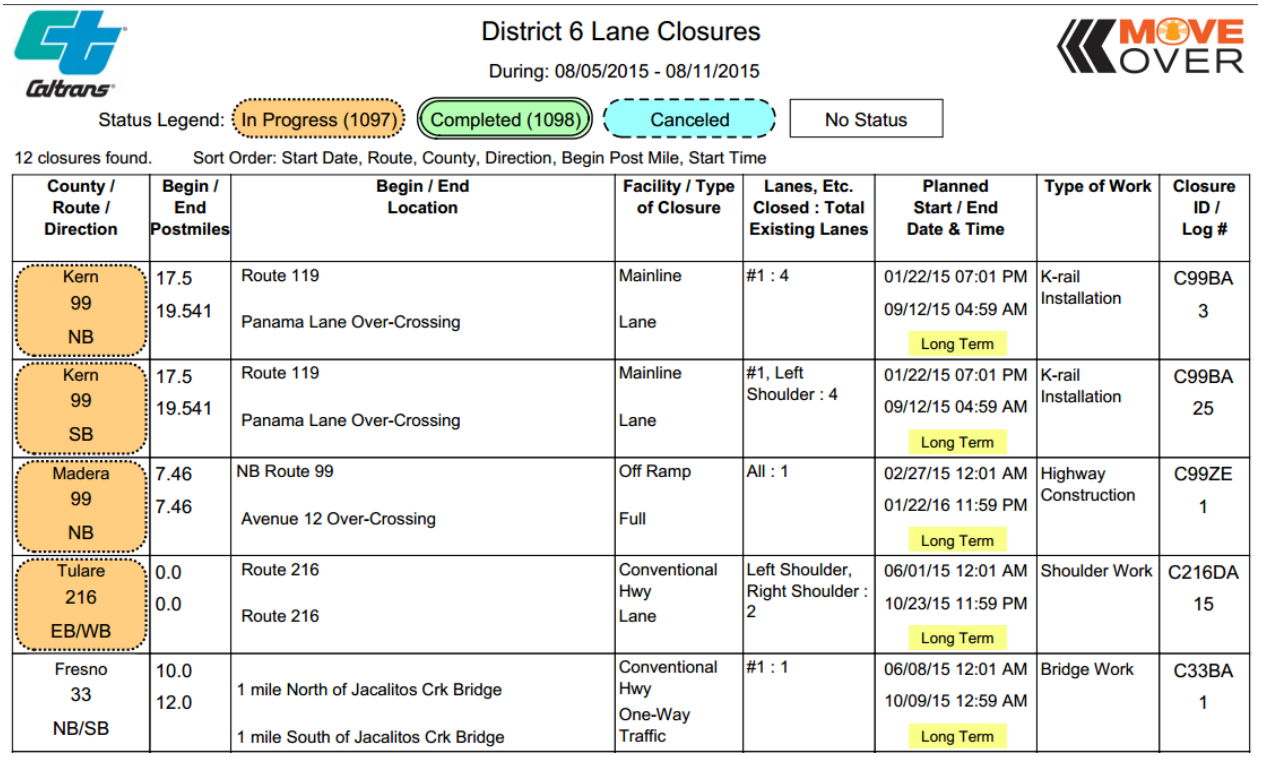


Figure 8: Caltrans Online Lane Closure System (24)



District 6 Lane Closures

During: 08/05/2015 - 08/11/2015

Status Legend: In Progress (1097) | Completed (1098) | Canceled | No Status

12 closures found. Sort Order: Start Date, Route, County, Direction, Begin Post Mile, Start Time

County / Route / Direction	Begin / End Postmiles	Begin / End Location	Facility / Type of Closure	Lanes, Etc. Closed : Total Existing Lanes	Planned Start / End Date & Time	Type of Work	Closure ID / Log #
Kern 99 NB	17.5 19.541	Route 119 Panama Lane Over-Crossing	Mainline Lane	#1 : 4	01/22/15 07:01 PM 09/12/15 04:59 AM Long Term	K-rail Installation	C99BA 3
Kern 99 SB	17.5 19.541	Route 119 Panama Lane Over-Crossing	Mainline Lane	#1, Left Shoulder : 4	01/22/15 07:01 PM 09/12/15 04:59 AM Long Term	K-rail Installation	C99BA 25
Madera 99 NB	7.46 7.46	NB Route 99 Avenue 12 Over-Crossing	Off Ramp Full	All : 1	02/27/15 12:01 AM 01/22/16 11:59 PM Long Term	Highway Construction	C99ZE 1
Tulare 216 EB/WB	0.0 0.0	Route 216 Route 216	Conventional Hwy Lane	Left Shoulder, Right Shoulder : 2	06/01/15 12:01 AM 10/23/15 11:59 PM Long Term	Shoulder Work	C216DA 15
Fresno 33 NB/SB	10.0 12.0	1 mile North of Jacalitos Crk Bridge 1 mile South of Jacalitos Crk Bridge	Conventional Hwy One-Way Traffic	#1 : 1	06/08/15 12:01 AM 10/09/15 12:59 AM Long Term	Bridge Work	C33BA 1

Figure 9: Caltrans Online Lane Closure System Example (24)

WISE (Work Zone Impact and Strategy Estimator)

WISE was created by FHWA to support decision plan and schedule of work zones in a mesoscopic level. WISE is a decision support system for use by planners and engineers to help them evaluate the impacts of work zones and determine strategies to reduce traffic impacts. WISE has the capability to evaluate the regional impact of various strategies such as day/night operations, innovative contracting, fast construction techniques, advanced maintenance of traffic plans and public information programs (See Figure 10). WISE can aid decision-making by sequencing reconstruction activity given limited resources and other constraints (25).

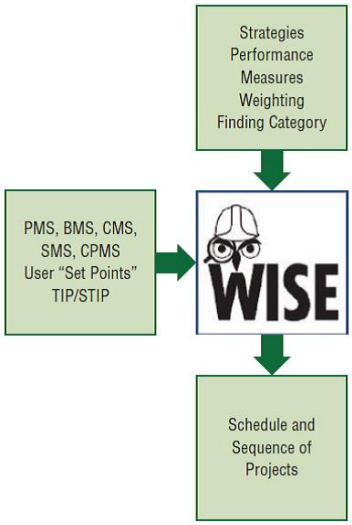


Figure 10: WISE Inputs and Outcomes (25)

The WISE software helps agencies assess the optimal sequencing of renewal projects, and help determine the cost-effectiveness of strategies to minimize, manage, and mitigate road user costs from safety or operational perspectives. Figure 11 shows the WISE interface. The tool is fully developed and is being tested in Iowa and Arizona using historical data to validate its parameters (26). In addition, pilot tests in Orlando, Maryland, Monterey Bay Area, and Tennessee are being tested to identify WISE software needs and to enable software demonstration and application (27). Detailed information on the WISE tool is presented in the subsection "In Depth Review of CIA and WISE".

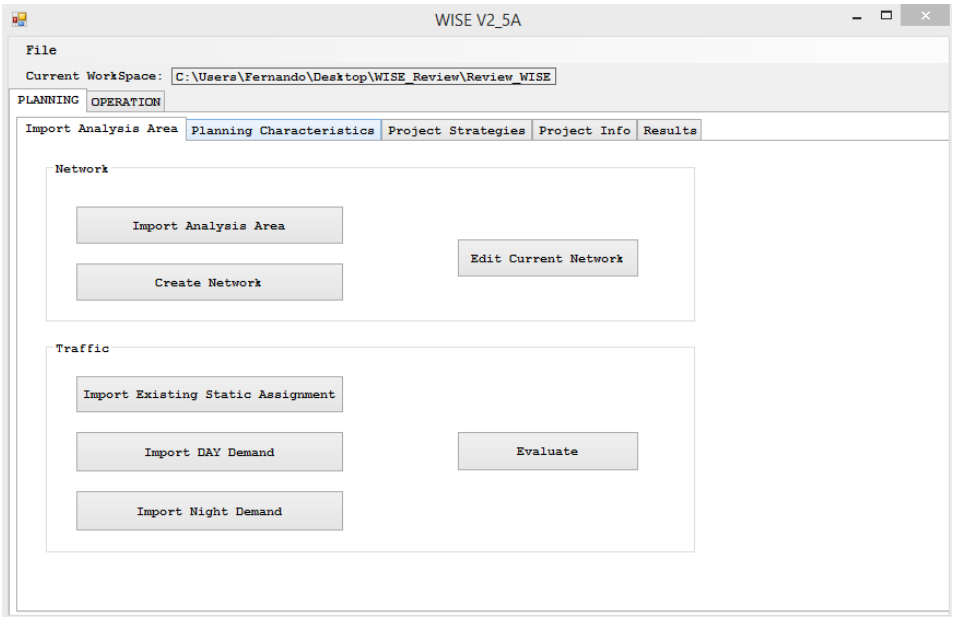


Figure 11: WISE Interface

Construction Impact Analysis (CIA)

CIA (28) was developed by Washington State Department of Transportation (WSDOT) as a mean for tracking and estimating construction projects' impact on the roadway both individually and aggregately. The concept was created to facilitate and manage the collaboration between different needs from all the construction projects scheduled in a certain area at same time frames.

The tool focuses on the collaborative multi-agency construction traffic planning effort based on the communication and coordination amongst projects and agencies in the state. These coordination efforts include information sharing on long-term and mid-term projects. It allows collection, validation, communication and analysis of expected traffic disruption.

As a result of work zone coordination efforts, WSDOT and the local and regional agencies involved recognize following benefits:

- Reduced potential for conflicting lane/road closures.
- Regularly scheduled meeting time for key personnel to discuss closures.
- Enhanced public information resources, such as maps posted to the WSDOT website that provides a detailed picture of the coordinated closures.
- Enhanced public information dissemination, reaching out a greater number of stakeholders across multiple affected locations.

Detailed information on the CIA tool is presented in the subsection "In Depth Review of CIA and WISE".

ENVISTA

Envista is a private web-based application that provides project details for infrastructure projects managed by different agencies in public rights-of-way. Its interface is web-based, allowing visibility and real-time information on street projects and activities being conducted by different agencies (29).

Envista enables the management of utility projects, public works, permitting, incidents, traffic, and events to optimize street performance, reduce costs, and minimize environmental impact. It also facilitates the exchange of information between different stakeholders, who can upload files, such as photographs, diagrams and sheets regarding the projects being coordinated, as well as GIS-information displayed in maps.

The software allows the creation of reports and summary of information for partners and public information. Figure 12 shows the Envista's map interface. Besides the map interface, a tabular form of the projects implemented is generated, allowing users to

provide additional details on the work being conducted. It is useful to identify conflicts and mitigate construction impacts due lack of project coordination.

Currently, City of Baltimore is using the technology along with Baltimore Gas Electric (29). The tool is used to manage projects and schedules of construction projects in the city street network.

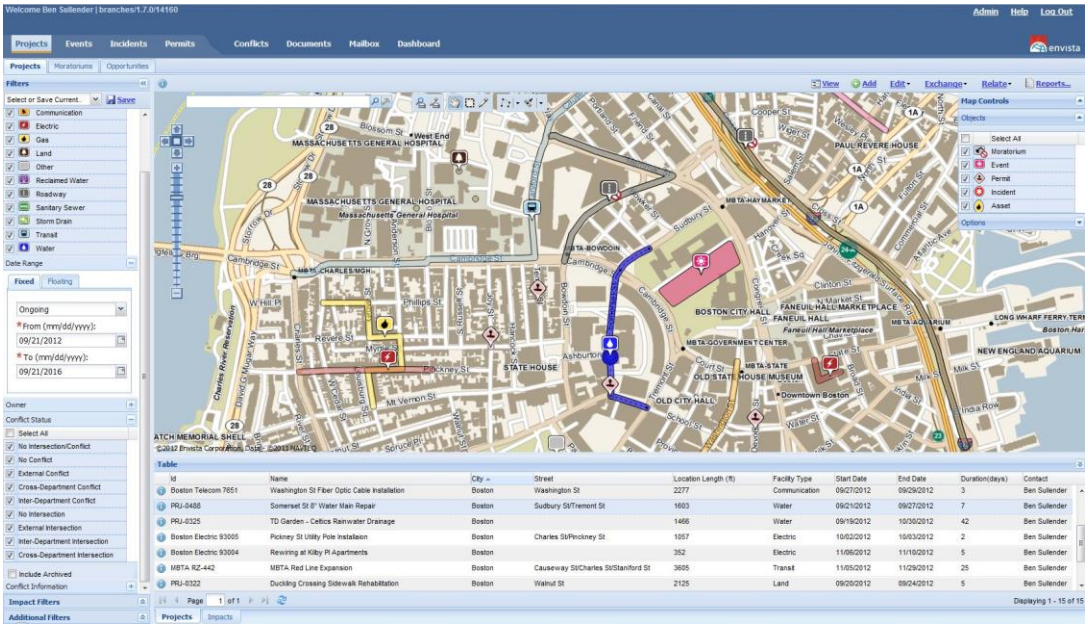


Figure 12: ENVISTA Interface (29)

Quickzone

Developed by Noblis using FHWA funding, QuickZone has been mentioned in FHWA guidelines as one of the several suggested tools to determine work zone delays. It is developed in Microsoft Excel. QuickZone considers traffic engineering parameters (as specified in the HCM) such as volume, truck percentage, lane width, etc. It has been widely used, tested, and validated by State and local DOTs. Current partners of FHWA using QuickZone include: Maryland State Highway Administration, Central Federal Lands Highway Division (CFLHD), Pennsylvania DOT, Ohio DOT, Wisconsin DOT, Washington DOT, Utah DOT, and North Carolina DOT. QuickZone's data requirements are comprehensive and highly detailed. It incorporates various factors impact traffic conditions at work zones. It is a tool that compares the impact of different work zone scenarios in terms of capacity, queue, delay and cost. For instance, users can compare the effect of nighttime work versus daytime work or the effect of diverting traffic to another road along a corridor. Currently, QuickZone version 2.0 is available and it is capable of the following operations (16):

- Quantify corridor delay resulted by capacity reduction,

- Estimation of delay impact based on different phases of construction,
- Impact of different scenarios for construction staging such as time (peak, off-peak), location and season (winter vs. summer),
- Tradeoff analysis between construction cost and user cost,
- Estimation of work completion incentives.

Approaches and Tools Used by Other Agencies to Manage Work zones

Similar to Caltrans, the Michigan DOT (MDOT) has an in-house developed tool to identify all scheduled construction work in a corridor The MDOT have also implemented a weekend closure within a long-term contract project and invited road maintenance, utility and survey forces to work on the interest within that time period (30).

The Missouri DOT (MoDOT) coordinates lane closures across district boundaries, and considers the statewide impact of work zones on traffic. Each district of the MoDOT has a work zone coordinator that organizes work zone activities within the district and communicates with other districts. The district coordinators are also responsible for scheduling multiple tasks in a single work zone rather than scheduling multiple lane closures in the same area (30).

The Oklahoma DOT found that, in many instances, when a maintenance job was completed, following utility work in the same area ruined the recent improvements. Then, in 1998, the Oklahoma DOT started coordinating its projects and activities with the local highway agencies, utility contractors and maintenance forces during the project planning phase to minimize traffic delays (30).

The District of Columbia Department of Transportation (DDOT) has developed a comprehensive Work Zone Project Management System (WZPMS) to facilitate the coordination of all work zones in DC area for a five-year period using a predictive model to determine potential impacts and identify work zone conflicts. All projects, including capital, utility, developer and special events, are integrated into the graphical, web-based software tool. The WZPMS includes three components — a Work Zone Tracking Tool, a Traffic Analysis Tool, and a Citywide Transportation Management Plan (30).

NYCDOT unveiled an online mapping system (**Figure 13**), guidance manual, and incentives to help improve coordination among utility companies, contractors, and agencies to minimize the number of times streets are dug up, reduce construction congestion, and extend the life of resurfacing projects (30). An executed agreement between NYCDOT and major utility companies provides for the monthly sharing of data regarding:

- All active NYCDOT street excavation permits.
- NYCDOT's list of "protected streets" (recently repaved/reconstructed streets that have a higher permitting fee and stricter restoration requirements if disturbed).

- NYCDOT's roadway resurfacing schedule, short-term utility excavation needs, and long-term utility project schedules.
- NYCDOT is one of the primary agencies interviewed in this project, and more detailed information on their state-of-practice is presented in the Interviews section.

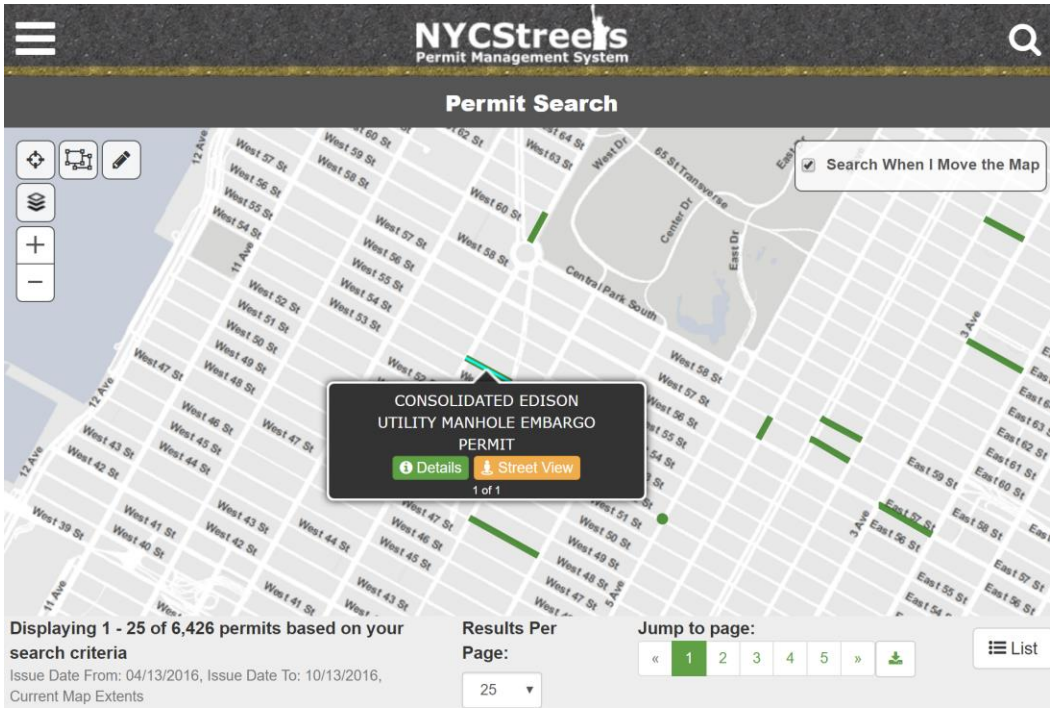


Figure 13 NYCStreets Permit Management System (31)

In summary, there are no generally accepted DOT policies in any municipality which address how agencies should coordinate or consolidate projects. In addition, only a few states utilize computer tools specific to regional or corridor based work zone coordination. State DOTs mostly coordinate for significant and long-term projects. There are more maintenance operations and utility work projects than long-term projects.

Simulation Tools

Microscopic simulation models simulate the movement of individual vehicles based on well-established car following and lane-changing theories. Typically, vehicles are assumed to enter a transportation network using a statistical distribution of arrivals (a stochastic process), and are tracked through the network over small time intervals (e.g., one second or a fraction of a second). Also, upon entry, each vehicle is assigned a destination, a vehicle type, and a driver type, among other parameters. In many microscopic simulation models, vehicle behavior in traffic is based on previously developed theories. Run-time of microscopic models is crucial, usually affected by the

network size and the number of simulation runs that need to be completed. Examples of microscopic simulation models include Traffic Software Integrated System/Corridor Simulation (TSIS/CORSIM), INTEGRATION, SimTraffic, Wide Area Traffic Simulation (WATSim), VISSIM, and Parallel Microscopic Traffic Simulator (PARAMICS).

Capabilities of Reviewed Software Tools

Table 1 displays the comparison between the functionalities among the selected software tools reviewed in this study. As seen in the table, none of the alternatives can provide all the specifications desired for scheduling and analyzing the traffic when placing a work zone. Specifically WISE and CIA, which are the focus of this study, complement each other in terms of functionality. CIA is user friendly and accessible for users due its connectivity functions and web-based platform, while WISE is much more complete in the analysis and produces a robust result in estimating conflicts and evaluating strategies to reduce work zone duration. Other software tools also have useful functionalities, such as Quickzone, which provides a quick and simple lane closure analysis, or the use of simulation tools (AIMSUN, VISSIM, PARAMICS) that demands intense modelling efforts as well extensive input data to reflect most recent traffic conditions.

Network Analysis is defined as the software tool's capability of working with a traffic network instead of a stand-alone highway corridor. This feature and the graphical interface feature go hand in hand, where the latter is defined as the tool's capability to work with geographical information systems (GIS) data and a map-based interface, allowing the user to enter or visually select links or segments for work zone area on the network. Some of the software tools, such as MS Project and MS Excel do not have this capability built in. Although it is possible to use Visual Basic Programming tools for manual coding, it is not a practical option. Other tools as CIA and Envista use web-based interfaces hosted from online mapping services, such as Google Maps or Microsoft Bing. WISE has a graphical interface build in a DynusT format, which can be imported form a shapefile or other GIS networks. After the files are converted it is relatively easy to manipulate and work with the graphical interface.

Table 1: Comparison of Reviewed Software Tools (23) (25) (28) (29)

	GLRTOC	**WISE**	**CIA**	**ENVISTA**
Network Analysis	Yes	Yes	Yes	Yes
Accessible Online	Yes	No	Yes	Yes
Graphical Interface	Yes	Yes	Yes	Yes
Analysis Period				
Short Term	Yes	No	No	Yes
Medium / Long Term	Yes	Yes	Yes	Yes

Special Events	Yes	No	Yes	Yes
Schedule / Coordination				
Gantt Chart	No	No	Yes	No
Evaluate Combined Projects	No	No	Yes	Yes
Automatically Finds Conflicts	No	No	Yes	Yes
Traffic Analysis				
Work Zone Impact Analysis	No	Yes	No	No
Traffic Diversion	No	Yes	No	No
Benefit Cost Analysis	No	Yes	No	No
Data Input				
Maintains a Work Zone Database	Yes	No	Yes	Yes
Project Manager Information	Yes	No	Yes	Yes
Traffic Volume	No	Yes	No	No

The tools are also compared based on whether they allow planning for different time horizons, i.e. analysis period. Short term projects tend to be completed on time and easier to handle, usually causing temporary congestion and specific traffic management needs for a few days or sometimes for several hours. Long term projects, on the other hand, demand better coordination for effective rerouting or other congestion mitigation strategies. WISE does not allow managing work zones in short time periods, since the minimum period of evaluation for the project is one month. CIA, although capable of managing short-term work zones, is not currently being used for this specific time horizon. Based on our interview with the WSDOT, they expressed their intension of including short-term work zones in the CIA tool.

For scheduling and coordination purposes, the frequently used output format of the reviewed work zone planning tools is the Gantt chart. A sequence of projects can also be an output in some cases, without the graphical representation. One important functionality of these tools listed in Table 1 is their ability to suggest merging of projects that take place at the same time to avoid closing the same lane or area twice in a short period of time. This is widely known as ‘opportunities’, since the output include them as suggestions to combine different projects that are scheduled simultaneously.

It is seen in Table 1 that only the WISE software tool is capable of estimating work zone impacts and conducting benefit-cost analysis of coordinating work zones. This is partly due to the fact that all other tools maintain an up-to-date work zone database, but not traffic volumes, an essential data source required for estimating the impact of work zones.

IN DEPTH REVIEW OF CIA AND WISE SOFTWARE TOOLS

The next two subsections present an in-depth review of the two major computer tools developed for work zone coordination, namely the CIA tool by WSDOT and the WISE tool by the FHWA.

The CIA Tool (28)

The CIA tool was developed in-house by WSDOT as a means for tracking and estimating construction projects' impacts on State's roadways both individually and aggregately, either in mid-term or long-term (28). Mid-to-long term construction coordination includes projects planned more than three months out and typically no more than two years into the future.

The tool is used by the WSDOT staff who do not have closure permitting authority and who are not routinely managing day-to-day traffic impacts. They look at construction projects/schedules from a traffic perspective. The tool helps them manage the overwhelming amount of work zone related data including: when, where and what construction closures are happening in the region for all jurisdictions. The use of this tool brings together the agencies responsible for the construction, maintenance, and operations. The CIA tool uses hot spots to help project teams communicate with each other while projects are still in design and before contracts are awarded. The main advantage of this tool is that it gets project teams to start talking early.

Each construction season, WSDOT analyzes upcoming projects to identify construction traffic "hot spots". Hot spots are areas where several roadway construction projects occur in close proximity at the same time and require increased multiagency coordination. This analysis is done more than a year in advance of the construction. The hot spot coordination meetings bring together project staff and partners to help project teams minimize and mitigate traffic impacts in advance of construction. The identified hot spots are updated each quarter and if significant changes to schedules or impacts occur, the analysis is revised.

Some regions may meet more often in between the annual construction meetings to further discuss and plan for upcoming projects. The Seattle area is a particularly hot spot of construction with a team of engaged staff meeting every two months to share information and identify risks and opportunities in the mid-term. Representatives from the affected cities, transit agencies, ports, and counties typically attend these meetings. The regular meetings are an easy way for the different offices to coordinate high impact lane closures and public information dissemination. Lane closure information is emailed to partners and made available at the WSDOT Web site.

Each quarter WSDOT also gathers traffic impact information for state, local, and private construction projects and events affecting roadways in eight western Washington

counties. This information is entered into WSDOT's CIA tool and used to create maps and Gantt charts to support coordination efforts. The materials can be customized to focus on specific geographic areas, time periods or severity of impact. The quarterly updates including identified hot spots are posted to the WSDOT Web site and provided to project teams, ensuring up-to-date information is available.

The CIA tool has three levels of access:

- **Viewer**: General user, can check status of projects and schedules already inputted, contact information of project managers, but are not authorized to insert new information in the program.
- **Editor**: Can modify the schedules and insert new information. Are responsible for updating the program quarterly with future projects and generating reports about the schedules.
- **Administrative**: Can add new jurisdictions and give permissions to other users.

These levels of access only differ on the permissions given to the employees, and usually the Editor level is the most commonly used level.

The tool is used to identify the ‘Hot Spots’, which are areas with high concentration of projects occurring in the same time. It’s important to notice that these projects may be special events, such as marathons, games, festivals, protests and other events that require capacity reduction and lane closure of the roads.

CIA tool is a web-based program that runs in Internet Explorer from any computer with internet access. The program has a graphical interface and the main tabs with functionalities are descripted in Table 2.

Table 2: CIA Tool Specifications

Tab	Description
Home	Home screen of the tool.
Project/Event	Includes project information and it's used to input data in the program. It contains different information of the project and the input is made according to data given by the project manager, such as duration of the project, preferred time of the day, constructor, project manager, geographical area and expected traffic impact.
Filter Data	Graphic interface of the tool used to visualize the data inputted in the maps and quality check the data registered in the Project/Event Tab.
Analyze Data	In this tab, it is possible to combine projects occurring in the same area. The software does not classify compatible projects, so every decision of combination must be guided by user's analysis. This tab allows to group and present project as groups, according to the 'Hot Spots'. The functionalities of this tab are not used by the agency in its fullest, but it allows to verify vicinity conflicts, corridor conflicts, same locations opportunities and vicinity opportunities.
Report	This tab contains a register of the reports created, allowing the data created to be exported to an Excel format. The reports can be saved and converted to other formats to be published in WSDOT's web site. The program SyncFusion is used for exporting the files, and includes Gantt Charts, summary of the events and schedule of projects.
Administrative	Not presented for the team, is used to give access to new users. Only available in the "Administrative Mode" level.

The work flow diagram shown in Figure 14 represents the adopted procedures to run the CIA tool.

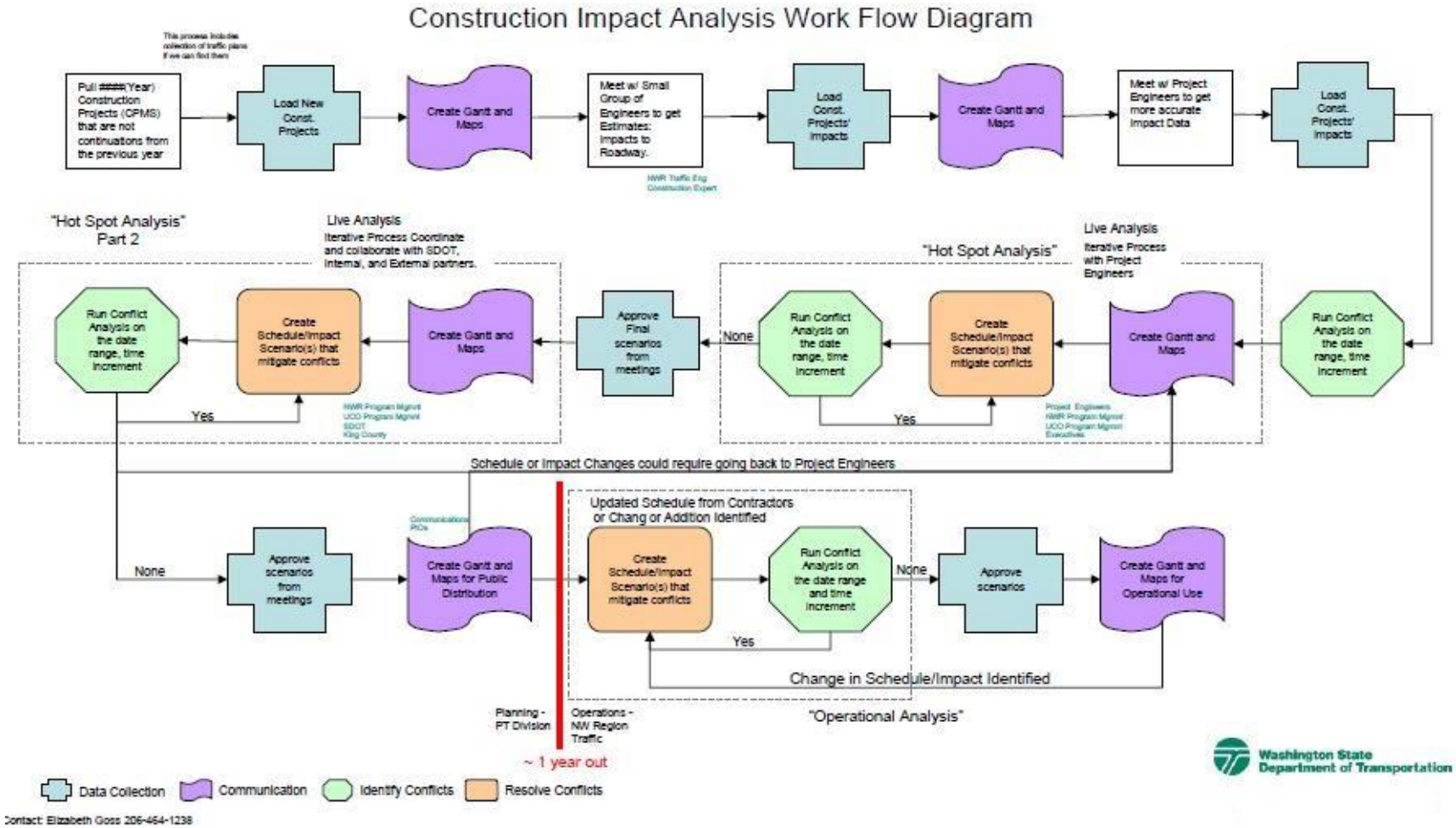


Figure 14: Work Flow Diagram to run the CIA Tool (28)

The process starts with previous work projects still ongoing in the tool, and ends with the new projects added every quarter. After the first round of analysis of the CIA tool, a small group of engineers evaluate the results and provide feedback on construction schedules, advise about the impacts of the projects and suggest possible consolidation of projects. An iterative process called 'Hot Spot Analysis' initiated between engineers and project managers, where the conflict analysis is run in the software and different scenarios are created with the schedules to mitigate the conflicts. After approved, a second round of analysis is conducted in collaboration with external partners and agencies to verify and communicate scenario. After this case is also approved, the Gantt Charts are generated to be published for the general public, and the contractors are communicated. The validation with the constructors is called 'Operational Analysis', where the schedules of the contractors are updated and additions are verified.

The tool is used to communicate traffic impacts to interested parties, either inside or outside WSDOT.

The tool can produce automated Gantt Charts, identifying by colors and patterns the impact of the work zone on the traffic, based on the categories shown in Figure 15. Although it is a very efficient chart that contains valuable information the estimated traffic impact is usually based on the experience of constructors or managers, and the expected level of complexity of the work zone.

Figure 15: Impact of Work Zones Legend (28)

Geographical information for locating work zones is determined by the project manager. The projects can be added according to state code of highway, or street name and crossings if it is a local road. The location can be easily visualized in the map, as the selected link is highlighted. Projects' time periods are classified in morning peak, midday, afternoon peak, and overnight and 24-hour periods.

The CIA tool is very useful for coordinating and organizing work zone schedules, but its dependence on user's judgement and project manager's experience limits its output quality. The usefulness of a similar tool for NYCDOT projects will be discussed in Task 4 of CIDNY project, namely "Develop an introductory course on Traffic Incident Management (TIM) response for transportation operators, customized to address unique congested condition of NYC highways."

Work Zone Impact and Strategy Estimator (WISE) (25)

WISE is a strategic planning tool with additional operation capabilities. It has two main interfaces that are used to evaluate the projects and generate the sequencing of them. Evaluation of strategies can be done by creating different scenarios and evaluating conditions and user delays calculated by the software (25).

- **Planning Module** (Project Sequencing Optimization Engine) is designed to create a sequence of the projects in the horizon, and it is the main focus of WISE software. In this module, it is possible to edit all the information of the projects being evaluated and load a static traffic assignment that will serve as input to create the schedule for the projects that minimizes the overall cost. Other costs, such as travel time reliability and environmental impacts are not considered in WISE tool.

- **Operation Module** is focused on the dynamic traffic assignment, it is mainly built upon an open source software called Dynamic Urban Systems for Transportation (DynusT). DynusT is a dynamic traffic simulation and assignment (DTA) software that allows the users to estimate the evolution of system-wide traffic flow dynamics patterns resulted from individual drivers seeking the best routes to their destinations responding to changing network demand, supply, or control conditions (32). This process can also be done with other traffic operational software selected by the user. WISE operation module process is more complex and depends on calibration and detailed information provided by users.

Data Input

WISE works with the concept of work spaces. Work spaces have a specific file structure that WISE relies upon to operate. This file structure consists of a primary work spaces folder, which is the main folder you save as your work spaces name during creation. All of the documents and subfolders are created or populated by WISE. Manual manipulation of these folders or documents is not necessary during regular use.

All work spaces must contain one valid network, which contains all projects. One important data requirement is that the network needs to be in DynusT format. The user has the option of importing a predefined network, creating a new network, or modifying the current network. WISE provides the option of importing an existing static traffic assignment or importing day and night demand and running the WISE OBA Evaluator.

WISE was specifically built on a platform of non-proprietary software DynusT to enable its free distribution. The underlying graphic user interface (GUI) for DynusT, called NEXTA, has both data input and simulation animation/data analysis features. However, it also has substantial limitations: for example, it only supports two-way streets and intersections, without highways, ramps, or one-way roads. Therefore, users are required to convert their existing network to a two-way configuration with intersections or develop

such a “stick network” following the directions in the user guide. A desirable future improvement would be to modify the WISE tool to interface directly with any commercial or non-proprietary network system. Based on the phone interview with WISE/DynusT developer team from Metropia on June 30 2016, the DynusT team is currently also developing their own GUI - DynuStudio. With DynuStudio, users will have the capability to convert GIS based planning networks to DynusT, manage scenarios, run DynusT, and visualize network simulation results for debugging, analysis and presentation purposes (33). This would enable WISE to easily evaluate large projects on interstates and corridors. Currently, WISE only considers a single construction project occurring on a single highway segment.

In the tests evaluated, the network conversion was one of the most critical parts of running the software, since frequently this conversion is prone to fail and produces networks that are not compatible with the original shapefile, presenting distorted links and attributes that needed to be manually corrected by the user (See Figure 16). Although some converters such as VISIM-DynusT converter, DynusT-VISSIM converter (34) are developed to assist network conversion, manual editing and checks are needed in most of the cases.

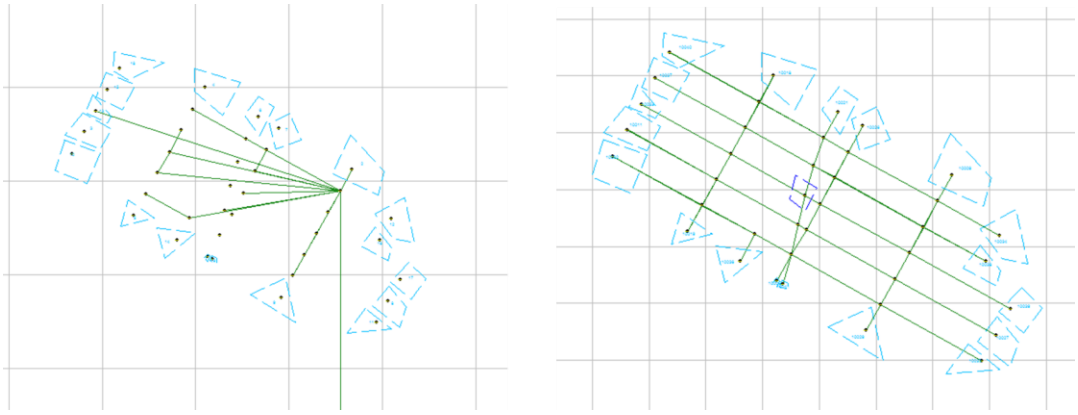


Figure 16: Example WISE Importing Error

Project Information

There are certain constraints to project information in WISE, as shown in Figure 17. The software does not have the ability to consider that a construction project might involve multiple roadway segments. Each project is assigned only to a single road link of the network, and this is a critical limitation of the software, since projects can frequently occur in longer or combined segments.

Another problem that needs attention is the fact that WISE does not set capacity back to 100% after the work zone is finished. It only works with demand reduce and construction duration reduce strategies. However, in practice, some projects increased capacity, and the program does not have the ability to recognize that the capacity has increased.

The work zone project information required by the WISE tool includes the time period of the day and the estimated traffic demand reduction that the work zone may cause. The WISE tool is successful in setting optimized time frames for a set of work zone projects; it is useful in identifying user costs based on delay and diversion, plus agency costs for different projects. It is also effective in discerning public involvement strategies. However, the Planning Module estimates for diversion are not robust; user-supplied estimates of diversion will be better in most cases, and diversion estimates developed by running a microsimulation model will be even better.

Field	GUI Value	Comment
Work zone speed	$5 \le x \le$ the original speed limit; integer	The work zone speed limit cannot be zero or cannot be faster than original speed limit.
User-supplied diversion rate	If user-defined diverge is TRUE, then $1 \le x \le 100$; integer. If user-defined diverge is FALSE, then $x = 0$	If the route divergence uses user-defined rate, then $1 \le x \le 100$; integer. If the route divergence computes diverge rate internally, then $x = 0$.
Day cost	Integer and nonnegative	
Night cost	Integer and nonnegative	Agency cost should be realistic.
Capacity/lane reduction	$x \ge 0.01$; float	Percentage of capacity reduction due to work zone construction. Should be greater or equal to 0.01.
Duration	Integer; $1 \le x \le$ (latest end time – earliest start time);	Note the caution below about duration-based strategies. Such strategies must not result in zero or negative duration.
Duration-based strategy*	If one project *i* was applied by a duration-based strategy *k*, then the duration of project $i \ge$ duration-based strategy + 1	Duration-based strategy cannot reduce the project duration to zero or negative.
Link	Single use	Each project is unique link.

Figure 17: Project Information Constraints in WISE (25)

Data Output

Outputs provided by WISE are consistent but limited for more complex evaluation. In the Planning Module, a sequence of the inputted projects is created and presented inside the software, as shown in Figure 18. The data required are difficult to handle and need to be refined in spreadsheets or other data processing software to be more user friendly and better interpreted. Also, from this module, there are no graphical solutions such as Gantt Charts, or even the ability to provide recommendations of combined projects and opportunities.

WISE has some limitations in generating schedule changes in linear corridors. Basically, along linear corridors, there is little interaction between the corridors, and therefore, little justification for making changes other than to simply let all corridor construction run concurrently.

In the Operational Module, simulation models other than DynusT can also be used to simulate the work zones. Then the diversion estimates can be manually input into the Planning Module to generate an update schedule (33). For example, one of the pilot studies used TransModeler software to estimate traffic diversion and model validation.

```
-----------------------------------------------------------
-------------- FEASIBLE PROJECT SEQUENCING ----------------

     ------------- DAY TIME SEQUENCING --------------

Project ID:  4
  Link:                  223   243
  Capacity Reduction:   0.33
  Original Speed:         45
  New Speed:              35
  Agency Day Cost = $    13000000

               ----------------------------------------
  Start Year:                                      2015
  Start Month:                                       11
  Project Link Avg. Flow (vph):                    1669
  Project Link Avg. Travel Time (min):             0.22
  Original Project Link Avg. Flow (vph):           9030
  Original Project Link Avg. Travel Time (min):    0.49

  -----------------------------------------------------------
     ------------ NIGHT TIME SEQUENCING -------------

  There were no night-time sequencing projects identified.

     ------------ JOINT TIME SEQUENCING -------------
```

Figure 18: Example of result provided by the Planning Module of WISE

Pilot Test

Pilot Tests were conducted by FHWA to evaluate the efficiency of the software before the release. Four pilot sites in Orlando, Maryland, Monterey Bay Area, and Tennessee were selected for testing, and the key criteria for selecting sites for a pilot test were the existence of a proposed program and sequence of projects on a corridor with a readily available travel demand network (27). Extensive automated routines were developed during the validation test to convert TransCAD network files to the simplified network required by WISE. Therefore, it was agreed to identify pilot sites that also used the TransCAD model, to facilitate the conversion process. With these criteria, the Orlando, Florida, I-4 projects and the Worcester, Massachusetts, Route 9 reconstruction areas were selected to test the Planning Module.

The interface between a microscopic model and the Planning Module was tested for the Orlando, Florida, site for the pilot test. The Orlando projects were used into a microscopic model and ran multiple times to test day and night operations for each project. The diversion percentage generated by each project was then manually entered into the WISE module. The optimal order of projects was then compared between the WISE Planning

Module, with default diversion values, and the microsimulation diversion values. In this case the TransCAD model for Orlando was used for the microsimulation. In addition, Monterey pilot also used network coding for DTA in TransModeler with modification in WISE. Maryland pilot used WISE tool with an existing activity-based model (27). Tennessee pilot identified extensive efforts are needed in mesoscopic model calibration.

WISE Limitations

Based on several tests from the research team and current status of the pilot projects, some highlights of the limitations of WISE based on the research team's practices and webinar discussion on October 11th, 2016 (27) are listed below:

- Current implementation is cumbersome to use for most MPO or DOT staff.
- Extensive manipulation of network data is required to make it usable in WISE.
- Present traffic re-assignment calculation makes little sense for larger projects that impact route choices at the origin-destination level.
- Integration with travel models should allow user to input delay and/or diversion calculations directly without the need for ad hoc detour calculations in WISE.
- WISE is not capable of properly handling complex sequencing of projects.
- There is no support for project phasing or for defining projects that span more than one link.
- It has node limitation (maximum 23,000 nodes).
- Detailed construction cost is not defined as input.
- WISE is currently limited to a handful of projects because it goes through an optimization process.

Interview with Metropia (WISE/DynusT Developer Team)

Metropia is involved in the development of DynusT and WISE software tools. Based on a phone conversation with the developer team on June 2016, several important developments vis-a-vis WISE tool were brought to the attention of the research team. The current WISE software is calling an old version of DynusT (3.1) with a third-party GUI provided by NEXTA for its operation module. The latest more stable DynusT version (Ver. 2016) and test model are provided to NYU team. After testing, the research team found that the new DynusT version is compatible with the current WISE tool, however, unexpected NEXTA errors still occurs during our testing of WISE software. Unfortunately, DynusT team has no control on NEXTA, and thus cannot fix NEXTA errors. As suggested by the developer team, a new powerful GUI called DynuStudio will allow users to convert GIS based planning networks to DynusT, edit networks and input additional information and manage scenarios. This GUI is under full control of the DynusT Team and its latest version 1.13 is available at http://www.rstintl.net.

Software Analysis

Both WISE and CIA tools evaluated in this report can be effective solutions for managing and operating work zones, although they have some specific characteristics that clearly distinguish one from the other.

CIA is used by WSDOT effectively to coordinate and manage the 'Hot Spots' of the state highways through a web-based interface. The main output is a graphical representation of the construction areas and a schedule that can easily be interpreted by a novice user, containing the information about the project such as expected period of the day to have lane closures and possible impact on the traffic.

CIA is a relatively simple but efficient tool to keep track of construction projects and coordinate intra-agency the efforts to combine work zones, even though this functionality is not explored at its fullest– for example the functionality of "opportunities" is still underutilized. The results presented by the software package are used mostly for information management and internal coordination, sometimes with users and stakeholders' engagement, and it could be expanded for traffic analysis and congestion mitigation

WISE, on the other hand, is also a useful software albeit with certain limitations. Its functionalities such as in-software traffic impact and cost analysis, and project sequencing are among the major highlights of this tool. It is capable to assess optimal sequencing, evaluate cost-effectiveness of strategies, both demand based strategies and duration based strategies, to reduce or mange road user cost. However, the interface is built in an open-source software which is not scalable and not user-friendly. Its GUI may encounter unexpected compatibility issues and report vague error messages. Contact with the developer team may be needed.

As currently designed, DOTs may find value in using WISE within the limits described considering its capabilities. The WISE program is a useful tool for coordinating and organizing work zone schedules, but it is highly dependent on the user's judgement and project manager's experience.

Based on our review of these software tools, none of them can address all the needs identified in this project for inter-agency coordination of work zone activities. Instead, a hybrid approach combining the best elements of each software seems to be the most feasible idea for having a complete tool for coordinating schedules and conducting traffic impact analysis along with a benefit-cost analysis that can be used to improve work zone related decisions. The specific requirements for this hybrid tool are determined after individual and in-depth interviews with the agencies operating in our region. They are presented in the next section.

INTERVIEWS WITH AGENCIES

This section details the in-depth interviews conducted by the research team with various transportation agencies determined in Task 2's Scope of Work. The objective of these interviews was to review the current state-of-practice related to roadway work zones by each of these agencies. The information presented below is based on the interviews conducted with the experts from these selected transportation agencies. Table 3 lists the names of interviewees, their affiliations, and the dates of each interview.

Table 3: List of Interviews

Interviewee	**Date**
NYCDOT / OCMC	***November 30, 2015***
Duane Barra – Director, Office of Construction Mitigation and Coordination	
Frank Mark – Executive Director, Technical Administration, Roadway Repair and Maintenance Division	
Andrew Weeks – Director, Modeling and Data Analysis	
Henry Tomarchio – Assistant Director, Citywide Pedestrian Ramp, Sidewalk Repair and Management	
TRANSCOM	***February 1, 2016***
Matthew Edelman – Executive Director	
Doug Heulitt – Regional Construction Coordinator	
PANYNJ	***February 8, 2016***
Armando Lepore – Principal Transportation Engineer / Planner	
Matthew Walker – Transportation Engineer	
MTA NYCT	***March 16, 2016***
Philip Speidel – Principal Transportation Planner, Operations Planning	
Hillary Cardoza-Cato – Principal Transit Management Analyst, Operations Planning	
Dawn Moore – Principal Transportation Planner, Operations Planning (Special Events)	
Isaac Takyi – Senior Director, Metropolitan Transportation Authority Information Technology (MTA-IT) Department	
NYCDDC	***May 13, 2016***
Jorge S. Tua – Director, Infrastructure Design 2	
NYSDOT (Region 1)	***September 14, 2016***
James Haggerty, Capital Region Traffic Management Center Manager	
Joseph Rutnik, Civil Engineer	
John Bassett, Director, System Optimization Bureau	

NYMTC	***September 28, 2016***
Gerry Bogacz, Planning Director	
NYSDOT (Region 11)	
Refat F. Habashy, Director, Operations Keith Hom, Senior Transportation Analyst, Traffic Raj Amin, ITS Program Manager, Traffic Bruce Ogurek, Director, Construction Uchenna Madu, Director, Planning and Project Development Christopher J. Alvarez, Principal, Construction Fred Lai, Regional Traffic Engineer, Traffic Edward Mark, TDM Manager, Planning	***March 1, 2017***
NYCDOT OCMC / IT&Telecom (Follow up meeting)	***March 24, 2017***
John Martin, Administrative project manager, OCMC Permits	
Mark Ryvkin, Computer System Manager, OCMC Permits	
Varghese Abraham, Director, Project Management Office of IT&Telecom	
Patrick McCambridge, Project manager, IT&Telecom	

The interviews for each agency were conducted by following a predetermined list of questions developed by the research team. The research team prepared ten general questions that were intended to identify the roles and responsibilities of various divisions within an agency and examples of work zone related activities with a focus on coordination, if any. In addition to the general questions, the team had also prepared several specific questions that focused on planning, operational and strategic aspects of work zones. The intent of these specific questions was to understand the agency specific policies followed to deal with reducing the impact of work zones via planning and intra and inter coordination and collaboration. The list of questions used in the interviews is given in Appendix A.

Each subsection below provides the detailed summary of the interviews conducted by the research team.

New York City Department of Transportation

The New York City Department of Transportation (NYCDOT) is a government agency that operates in the five boroughs of New York City (NYC), and it is responsible for the management of local transportation infrastructure. NYCDOT focuses on the safety and effective movement of people and good within the City and maintains the condition of 6,000 miles of streets and highways, over 12,000 miles of sidewalk, 789 bridge and tunnels, 12,700 signalized intersections, 315,000 street lights, and 69 million linear feet of markings. NYCDOT cooperates with other local agencies in programs to provide the adequate conditions to keep the City operating.

Current Practice of NYCDOT

It was determined that there are various divisions within the department that are responsible for conducting either short or long term constructions projects. These are:

- Construction Mitigation and Coordination
- Resurfacing and Reconstruction of Streets
- Sidewalk Repair and Management
- Capital Projects
- Bridges
- Signs and Signals

The descriptions of these projects are presented below.

Construction Mitigation and Coordination: The Office of Construction Mitigation and Coordination (OCMC) of NYCDOT is a point organization to coordinate work zone impact with all private and government contractors including DOT, other city NYC Agencies, NYSDOT, Utilities, Transportation Authorities, etc. OCMC uses one of the most advanced permitting systems in US. Construction activity in NYC is heavily regulated and OCMC issues almost half a million of construction permits a year. It is involved in numerous inter-agency and citywide coordination activities.

The New York City Department of Transportation publishes the Street Works Manual, which is a guideline to everyone that performs work in the City's streets, such as utility work, installations, and even adjacent buildings which require lane closure of special needs or deliveries during the constructions (35). This department also plays an important role in issuing permits to stakeholders in the city. Most of the work that OCMC oversees is done by outside contractors such as utility companies. In total, the City is responsible for issuing over 150 different types of sidewalk and roadway permits that cover street opening and closure, sidewalk construction and placing work machines in the area. The agency issues over a half million permits a year.

OCMC reviews all construction permit applications put by stakeholders, and provide the construction activity stipulations for permits to allow the work to occur with minimal disruption to traffic, and improve safety operations. This office works closely to the Office of Permit Management, which is responsible for permittee registration and support. Please note that during our interview with NYCDOT, only OCMC was available for interviews.

In order to apply for a permit, an applicant must register in person with NYCDOT first by submitting a Permittee Registration Application (35). The permittee registration is a one-time process. However, registered applicants must keep all insurance and general

information up to date, which must be done in person at the central Permit Office (35). Anyone currently registered with NYCDOT and who has an active Permittee Number is eligible to apply for non-emergency construction work permits online through NYCSTREETS (36). More than 90% of all permits are applied for and issued online[3]. Figure 19 demonstrates the basic permit application process for Non-Emergency Work.

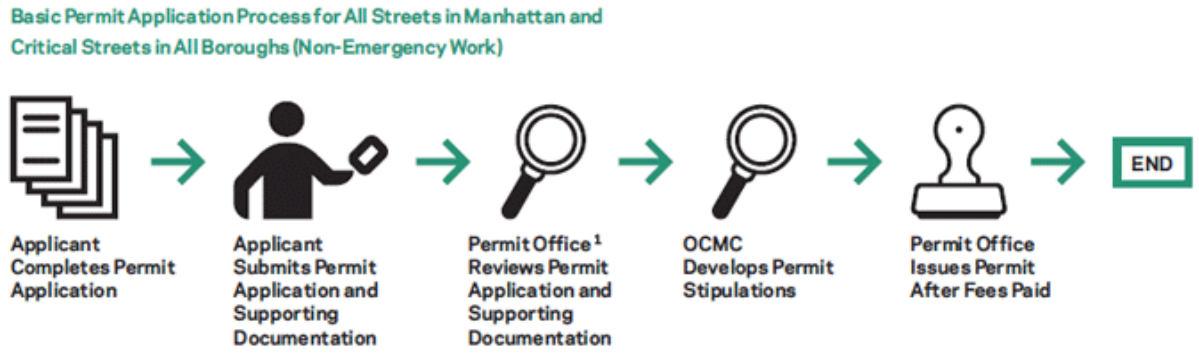
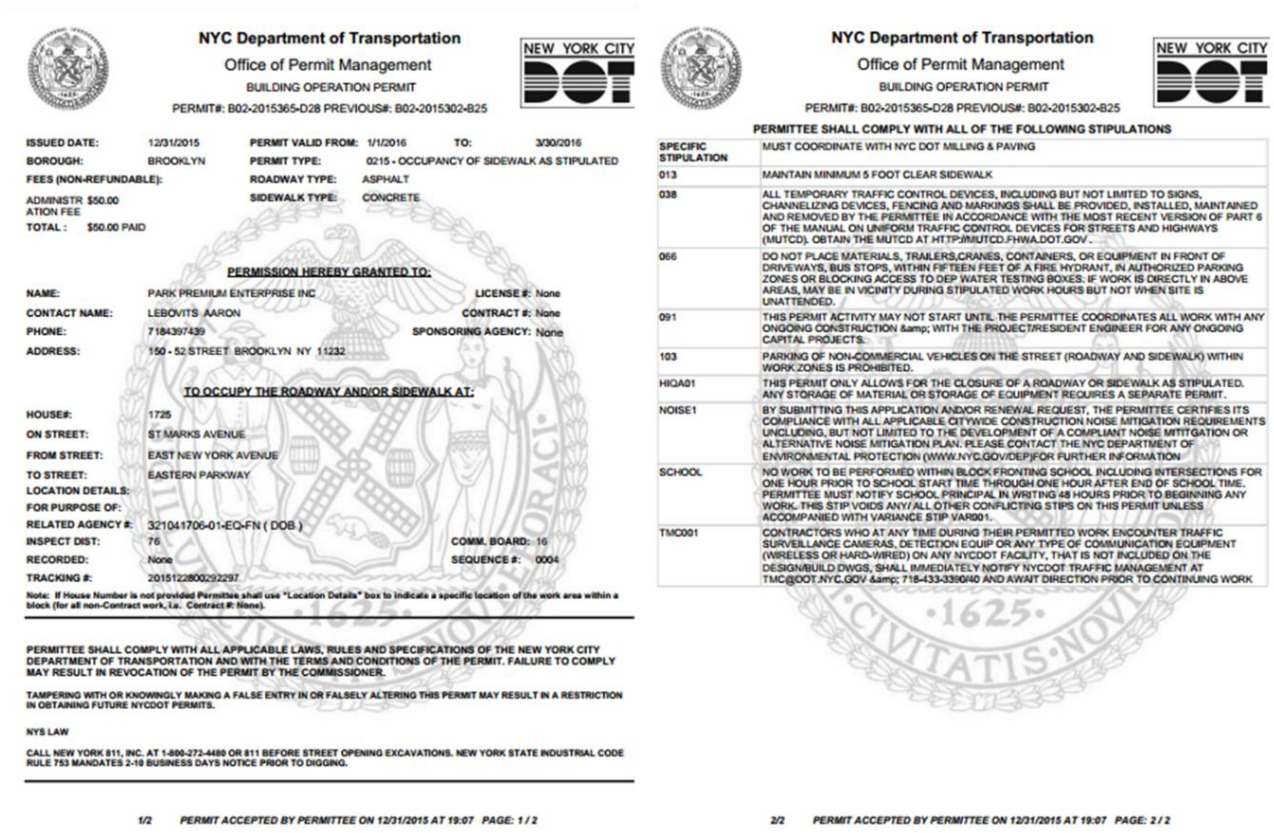


Figure 19: The basic permit application process (Non-Emergency Work) (35)

After the permit is requested and approved by the Permit Office, OCMC is responsible for providing the guidelines and minimum requirements for the applicant to avoid disruptions in traffic and pedestrian flows. These projects are usually small or medium size, not requiring extensive data analysis to prevent excessive congestion. In case of arterials and corridors with larger volumes, OCMC contacts the Modeling and Data Analysis division with the construction mitigation and coordination bureau to request a data analysis and even small modelling in some cases.

The permits issued by this office are available online via NYCSTREETS platform, and can be accessed at www.nycstreets.net. NYCSTREETS provides access to all NYCDOT Construction Permits through flexible Search and Mapping interface. A sample permit is shown in **Figure 20**Error! Reference source not found.**.** Based on the feedback from OCMC, NYCSTREETS platform is already used by the New York City Department of Design and Construction (DDC) and has a number of build-in conflict resolution procedures designed to coordinate work activities at capital project locations. But OCMC clearly stated that there is still room for improvement which may include automated “live” data exchange with multiple agencies and smart mapping and database tools, and additional review staff. NYCDOT construction permits comprise the most complete repository for the actual construction activity in the city by all government and private contractors. DOT IT&T is working on a comprehensive upgrade (Pavement Works) of DOT’s current MOSACS Capital Projects tracking application which will be fully integrated with NYCSTREETS.

[3] As per NYCDOT OCMC comments and feedback from the review meeting with NYCDOT on March 24th and May 16th, 2017.



NYC Department of Transportation
Office of Permit Management
BUILDING OPERATION PERMIT
PERMIT#: B02-2015365-D28 PREVIOUS#: B02-2015302-B25

ISSUED DATE: 12/31/2015 PERMIT VALID FROM: 1/1/2016 TO: 3/30/2016
BOROUGH: BROOKLYN PERMIT TYPE: 0215 - OCCUPANCY OF SIDEWALK AS STIPULATED
FEES (NON-REFUNDABLE): ROADWAY TYPE: ASPHALT
ADMINISTR ATION FEE $50.00 SIDEWALK TYPE: CONCRETE
TOTAL : $50.00 PAID

PERMISSION HEREBY GRANTED TO:

NAME: PARK PREMIUM ENTERPRISE INC LICENSE #: None
CONTACT NAME: LEBOVITS AARON CONTRACT #: None
PHONE: 7184397439 SPONSORING AGENCY: None
ADDRESS: 150 - 52 STREET BROOKLYN NY 11232

TO OCCUPY THE ROADWAY AND/OR SIDEWALK AT:

HOUSE#: 1725
ON STREET: ST MARKS AVENUE
FROM STREET: EAST NEW YORK AVENUE
TO STREET: EASTERN PARKWAY
LOCATION DETAILS:
FOR PURPOSE OF:
RELATED AGENCY #: 321041706-01-EQ-FN (DOB)
INSPECT DIST: 76 COMM. BOARD: 16
RECORDED: None SEQUENCE #: 0004
TRACKING #: 2015122800292297

Note: If House Number is not provided Permittee shall use "Location Details" box to indicate a specific location of the work area within a block (for all non-Contract work, i.e. Contract #: None).

PERMITTEE SHALL COMPLY WITH ALL APPLICABLE LAWS, RULES AND SPECIFICATIONS OF THE NEW YORK CITY DEPARTMENT OF TRANSPORTATION AND WITH THE TERMS AND CONDITIONS OF THE PERMIT. FAILURE TO COMPLY MAY RESULT IN REVOCATION OF THE PERMIT BY THE COMMISSIONER.

TAMPERING WITH OR KNOWINGLY MAKING A FALSE ENTRY IN OR FALSELY ALTERING THIS PERMIT MAY RESULT IN A RESTRICTION IN OBTAINING FUTURE NYCDOT PERMITS.

NYS LAW

CALL NEW YORK 811, INC. AT 1-800-272-4480 OR 811 BEFORE STREET OPENING EXCAVATIONS. NEW YORK STATE INDUSTRIAL CODE RULE 753 MANDATES 2-10 BUSINESS DAYS NOTICE PRIOR TO DIGGING.

1/2 PERMIT ACCEPTED BY PERMITTEE ON 12/31/2015 AT 19:07 PAGE: 1 / 2

NYC Department of Transportation
Office of Permit Management
BUILDING OPERATION PERMIT
PERMIT#: B02-2015365-D28 PREVIOUS#: B02-2015302-B25

PERMITTEE SHALL COMPLY WITH ALL OF THE FOLLOWING STIPULATIONS

SPECIFIC STIPULATION	
	MUST COORDINATE WITH NYC DOT MILLING & PAVING
013	MAINTAIN MINIMUM 5 FOOT CLEAR SIDEWALK
038	ALL TEMPORARY TRAFFIC CONTROL DEVICES, INCLUDING BUT NOT LIMITED TO SIGNS, CHANNELIZING DEVICES, FENCING AND MARKINGS SHALL BE PROVIDED, INSTALLED, MAINTAINED AND REMOVED BY THE PERMITTEE IN ACCORDANCE WITH THE MOST RECENT VERSION OF PART 6 OF THE MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES FOR STREETS AND HIGHWAYS (MUTCD). OBTAIN THE MUTCD AT HTTP://MUTCD.FHWA.DOT.GOV .
066	DO NOT PLACE MATERIALS, TRAILERS,CRANES, CONTAINERS, OR EQUIPMENT IN FRONT OF DRIVEWAYS, BUS STOPS, WITHIN FIFTEEN FEET OF A FIRE HYDRANT, IN AUTHORIZED PARKING ZONES OR BLOCKING ACCESS TO DEP WATER TESTING BOXES. IF WORK IS DIRECTLY IN ABOVE AREAS, MAY BE IN VICINITY DURING STIPULATED WORK HOURS BUT NOT WHEN SITE IS UNATTENDED.
091	THIS PERMIT ACTIVITY MAY NOT START UNTIL THE PERMITTEE COORDINATES ALL WORK WITH ANY ONGOING CONSTRUCTION & WITH THE PROJECT/RESIDENT ENGINEER FOR ANY ONGOING CAPITAL PROJECTS.
103	PARKING OF NON-COMMERCIAL VEHICLES ON THE STREET (ROADWAY AND SIDEWALK) WITHIN WORK ZONES IS PROHIBITED.
HIQA01	THIS PERMIT ONLY ALLOWS FOR THE CLOSURE OF A ROADWAY OR SIDEWALK AS STIPULATED. ANY STORAGE OF MATERIAL OR STORAGE OF EQUIPMENT REQUIRES A SEPARATE PERMIT.
NOISE1	BY SUBMITTING THIS APPLICATION AND/OR RENEWAL REQUEST, THE PERMITTEE CERTIFIES ITS COMPLIANCE WITH ALL APPLICABLE CITYWIDE CONSTRUCTION NOISE MITIGATION REQUIREMENTS (INCLUDING, BUT NOT LIMITED TO THE DEVELOPMENT OF A COMPLIANT NOISE MITIGATION OR ALTERNATIVE NOISE MITIGATION PLAN. PLEASE CONTACT THE NYC DEPARTMENT OF ENVIRONMENTAL PROTECTION (WWW.NYC.GOV/DEP)FOR FURTHER INFORMATION
SCHOOL	NO WORK TO BE PERFORMED WITHIN BLOCK FRONTING SCHOOL INCLUDING INTERSECTIONS FOR ONE HOUR PRIOR TO SCHOOL START TIME THROUGH ONE HOUR AFTER END OF SCHOOL TIME. PERMITTEE MUST NOTIFY SCHOOL PRINCIPAL IN WRITING 48 HOURS PRIOR TO BEGINNING ANY WORK. THIS STIP VOIDS ANY/ALL OTHER CONFLICTING STIPS ON THIS PERMIT UNLESS ACCOMPANIED WITH VARIANCE STIP VAR001.
TMC001	CONTRACTORS WHO AT ANY TIME DURING THEIR PERMITTED WORK ENCOUNTER TRAFFIC SURVEILLANCE CAMERAS, DETECTION EQUIP OR ANY TYPE OF COMMUNICATION EQUIPMENT (WIRELESS OR HARD-WIRED) ON ANY NYCDOT FACILITY, THAT IS NOT INCLUDED ON THE DESIGN/BUILD DWGS, SHALL IMMEDIATELY NOTIFY NYCDOT TRAFFIC MANAGEMENT AT TMC@DOT.NYC.GOV & 718-433-3390/40 AND AWAIT DIRECTION PRIOR TO CONTINUING WORK

2/2 PERMIT ACCEPTED BY PERMITTEE ON 12/31/2015 AT 19:07 PAGE: 2 / 2

Figure 20: Example of Permit Issued for Construction Work (37)

The research team initially received a sample permit dataset from NYCDOT on May 5th, 2016 with a follow-up update of the dataset on July 25th, 2016. The sample dataset includes the following information:

- Permit records in 2015 (550,691 records)
- Stipulation records by month in 2015
- Text reference for stipulation type ID

Permit records include information such as permit number, permit type, and location details. Stipulation records include information about permit number, stipulation type ID and text description of stipulation type. **Figure 21** illustrates the relationship between the records and online portal.

The research team also identified some limitations in NYCDOT's current permit data in terms of the overall objectives of this project. Chief among these is that NYCSTREETS construction permits are not designed to track actual work time spent by contractor onsite but specify a date/time window within which contractor allowed do its work mainly due to the very dynamic nature of construction activities on city streets. Current system has no specific field for capturing date/time window, the date/time window information goes

inside the text of the stipulation itself. This is an upgrade OCMC is planning to implement in a year[4].

The following actions have the potential to improve the Permit Data:

- A new functionality can be developed to auto extract related text information about construction activity including specific work days, hours and number of open/closed lanes and days from STIP records and incorporate them into the Permit Records. This is already included in the proposed OCMC's upgrade plans[5].
- A unified database to link the future upgraded MOSACS Capital Projects tracking application, NYCSTREETS along with utilities related data and traffic and transportation network data is recommended.

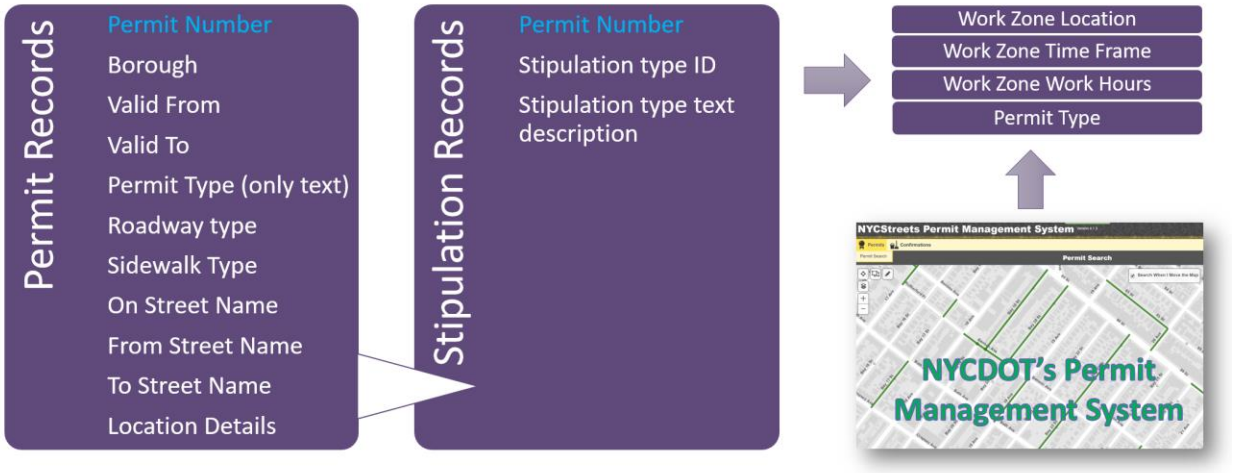


Figure 21 NYCDOT Permit records, stipulation records and online web portal

Resurfacing and Reconstruction of Streets: Resurfacing and reconstruction of streets are conducted by the Roadway Repair Division of NYCDOT. The most common process is milling (grinding off the top layer of asphalt or surface of a roadway), which is the first step for repaving. This process requires special placement of equipment, which is noisy and requires lane closure during the process.

The schedule of this work is predetermined by the division, which focuses on coordination with community boards in the neighborhoods to determine needs and special assignments for resurfacing. Besides, the division has a regular schedule for the year with priority areas that need to be completed.

[4] Based on the comments received from OCMC on March 2017.
[5] Based on the comments received from OCMC on March & May 2017.

The schedule for resurfacing is provided online in the NYCDOT website (36). An example schedule for the week of March 6 is shown in Figure 22. The schedule is updated weekly for each borough, indicating arterials and streets that will have operations for the next week. Since the resurfacing work takes a relatively shorter amount of time and relies on the available crew to complete the job, planning for these type of work is done on a daily or weekly basis. Resurfacing work does not usually require traffic impact analysis. The hours of operation are also determined based on the availability of man power for conducting the resurfacing work.

Once a street is resurfaced, it becomes a protected street for five years. NYCDOT will only issue street opening permits for protected streets if the work is critical. Repairs to potholes or other street defects can, however, be performed on protected streets.

Street reconstruction, which is more complex because it includes long-term upgrades, including upgrades to the underlying infrastructure. This work usually includes curb and sidewalk reconstruction, and it is conducted under safety improvements request or identified needs. Department of Design and Construction (DDC) is responsible in reconstruction, since it is considered a long-term project and can take up to five year from the conception to the complete delivery.

Brooklyn
Milling & Paving Schedule
March 6, 2016 to March 12, 2016

Date	SA#	Location	CB	Area
Sunday 3-6-16		No Work		
Monday 3-7-16	 K2013-17-04 K2011-17-02	Contractor Milling - Nights Glenwood Road (Albany Ave to Schenectady Ave) Utica Ave (Kings Hwy to Clarkson Ave) Maintenance	 17 17	 Farrgagut Farrgagut
Tuesday 3-8-16	 K2011-17-02	Contractor Milling - Nights Utica Ave (Kings Hwy to Clarkson Ave) Maintenance	 17	 Farrgagut
Wednesday 3-9-16	 K2011-17-02	Contractor Milling - Nights Utica Ave (Kings Hwy to Clarkson Ave) Maintenance	 17	 Farrgagut
Thursday 3-10-16	 K2011-17-02	Contractor Milling - Nights Utica Ave (Kings Hwy to Clarkson Ave) Maintenance	 17	 Farrgagut
Friday 3-11-16	 K2011-17-02	Contractor Milling - Nights Utica Ave (Kings Hwy to Clarkson Ave) Maintenance	 17	 Farrgagut
Saturday 3-12-16		No Work		

*Schedules are subject to change due to inclement weather or emergencies

Figure 22: Weekly Resurfacing Schedule (36)

Capital Projects: Capital Projects are major roadway construction projects that may include reconstruction of segments and safety improvements or design changes. The design of capital projects is guided by the NYCDOT Design Specification Manual and is usually identified in collaboration with the community boards. Capital projects take a

longer time than those constructed in-house because extensive scope of work, the need for detailed surveys and design and increased inter-agency coordination and approvals.

The capital program is planned, funded, and initiated by NYCDOT and built by Department of Design and Construction (DDC). It also may include several other stakeholders besides the community and DDC. These projects can take several years to be completed, therefore require intense and complete studies before initiate, most of the times including simulations to determine rerouting and hours of operation. This process can be done in-house (along with the Modeling and Data Analysis division) or by consultants. The City has a four-year Capital Commitment Plan, which is updated three times a year and tracks the status of current projects. Also, the City is responsible for the 10-year Capital Strategy, updated every 2 years.

Bridges: NYCDOT is responsible for almost 800 bridges in the five boroughs, including the famous Brooklyn, Manhattan, Williamsburg and Ed Koch Queensboro Bridges. Some of these bridges, besides the high traffic volume that utilizes the infrastructure, are also considered landmarks of the City, and therefore require the utmost attention and constant maintenance. The bridges are inspected annually, generating a report that indicates recent and planned maintenance, and also special needs.

The Bridges Division is also responsible for managing inspection after incidents such as truck strikes that can compromise the bridge structure and may need emergency repairs. No interviews were conducted with this team, although it is known that capital projects and maintenance projects in bridges require some level of traffic analysis and rerouting to avoid creating excessive congestion in the areas. This unit was not interviewed at this moment because their projects require traffic impact analysis, and for larger projects, they rely on OCMC and the traffic modelling team to review consultants' data and sometimes conduct traffic impact analysis in house. OCMC and Modelling and Data Analysis team were interviewed.

Sidewalk Repair and Management: According to the Section 19-152 of New York's Administrative Code, "*property owners are responsible for installing, repairing and maintaining sidewalks adjoining their properties*". The Sidewalk Repair and Management Division is responsible for inspecting sidewalk work and operations, indicating areas that need repairs. Since the NYCDOT responsibility in this area is mostly managing and inspecting the conditions of sidewalks, and not the repair itself, this division is not responsible for work zones and lane closures. NYCDOT inspects sidewalks throughout the city to ensure that they are safe. The inspectors are sent to properties based on specific criteria, including blocks where injuries were reported to the City or where complaints were filed. However, even they are not related to street closure, their work is to also inspect safety elements and designs of street work that may require pedestrian diversion, assuring that the pedestrians have a clear and safe way to cross the street work.

Highway Inspections and Quality Assurance (HIQA): HIQA is the Permit Enforcement Unit that carries multiple responsibilities to assure compliance with permit stipulations and quality of roadway restoration. HIQA's mission includes maintaining the integrity of the streets, increasing the level of safety for both pedestrians and vehicles, expediting the flow of traffic, for both pedestrian and vehicular traffic around the construction zones (38). Its roles and responsibilities involve street excavations, building operations (new or renovated buildings), emergency permits (street and utility access cover openings), sidewalk construction, and NYS Arterial Highway Contracts (38). HIQA enforcement plays a very critical role since a large percent of congested areas around construction zones is due to contractors which do not follow permit stipulations. HIQA also continuously verifies proper justification for emergency work (more than 35,000 Street Opening and Emergency Manhole Opening permits per year).

The NYCDOT interview is summarized in Table 4.

Table 4: Summary of NYCDOT Interview

	Overall	**OCMC**	**Sidewalk Repair and Management**	**Traffic Modeling**	**Roadway Repair Division**	**HIQA[6]**
1. Main Role	Manage city infrastructure (mostly streets)	Issue permits	Manage sidewalks	Predict impact	Resurface streets	Permit Enforcement
2. Characteristics of Work Zone	Usually executed by contractors	Provide guidance and requirements to implement	Supervision and inspection requirements	Provide data analysis and recommendations for diversions routes when needed	Construction and repaving	Assure compliance with permit stipulations and quality of roadway restoration
2.1. Duration	Short	Variable	Short	Long	Short	Variable
2.2. Typical Work Zone	Resurface streets, curb management, design elements	Not physically responsible for deployments	Inspection of constructions blocking sidewalks	Capital Projects	Continuous resurface of street	Monitor active construction sites
3. Database	Spreadsheets and permit database online	Maintains a database online, open to everyone (nycstreets.org)	Spreadsheet	Migrating to new online system	Spatial Streets Smart (SSS) web-based project management database[7]	N/A[8]
4. Guidance and Procedures	Each department has its priorities and procedures	NYCDOT Highway Rules and Street Works Manual[9]	Inspection is done based on minimum required: pedestrian movements are prioritized	N/A	Observe minimum requirements determined for each work zone: number of lanes to be maintained, work hours, route diversion	HIQA inspects work sites for compliance with Title 19 of the NYC Administrative Code, NYC DOT Rules and Regulations, NYC DOT specifications and NYC DOT permit stipulations.
5. Institutional Coordination (Intra-agency)	Mainly informal, based on communication and developed relationship with key players	Organizational charts with information flow and identification of key roles with respect to work zone coordination might exist	Organizational charts with information flow and identification of key roles with respect to work zone coordination might exist	No organizational charts or flow charts with information flow and identification of key roles with respect to work zone coordination	Organizational charts with information flow and identification of key roles with respect to work zone coordination might exist but they are not	N/A

[6] Information about HIQA unit is obtained from Street Works Manual (35), http://www.nyc.gov/html/dot/html/infrastructure/hiqa.shtml and https://www1.nyc.gov/assets/international/downloads/pdf/DOT%20UN%20Presentation.pdf

[7] Based on the comments received from OCMC on May 2017.

[8] Sections with no available information is marked as N/A.

[9] Based on the comments received from OCMC on May 2017.

		but they are not available to the research team.[10]	but they are not available to the research team[11].		available to the research team.	
6. Public Outreach	Using signs and direct channels to communicate work ahead of time	Emails list, meetings and temporary signs are used to notify community of work in streets. Complains by community addressed to DDC	Not involved in this process	Not involved in this process	Communication with Community Boards to define needs and priorities in street resurface	N/A
7. Modeling	Larger projects may require modelling, still in progress of implementing	On large projects	N/A	Only larger projects	Not needed, short term projects don't require it	N/A
8. Coordination	Coordinate with community and stakeholders.	Coordinates with different stakeholders, including agencies and private companies	Involved in residential projects	Coordinates projects with PANYNJ, TMC, Traffic Operations Unit	Utility companies monthly contacted, capital projects scheduled	The research team does not have information related to this item.
8.1. Management and partnerships	Coordinates with different agencies and stakeholders, has a fundamental role in managing permits for constructions	Works with multiple agencies closely such as DDC or TRANSCOM through regular meetings and other means of communication	Responsible for sidewalk repairs, pedestrian ramp installations, and Citywide concrete programs.	Reactive to hot areas - places where big projects are scheduled to happen ahead	Short terms projects don't require this level of planning in most cases - work planning is done in daily/weekly basis	Partner with different agencies, including Department of Buildings, Department of Sanitation, Department of Consumer Affairs, Department of Parks and Recreation, and Department of Environmental Protection
9. Safety Concerns	Vision Zero is a key program focuses on protecting pedestrian / exposed groups to incidents and fatalities. Directly applied to work zones, it addresses concerns mostly with worker safety.	In the context of Vision Zero, pedestrian movements at work zone locations are prioritized. Buildings and operations manages work site safety.	Inspect safety elements and designs of street work that may require pedestrian diversion[12]	VMS signs help avoid speeding in work zones.	Freeways are more affected by Driver's First Program	HIQA monitors active construction sites to ensure that the safe, smooth flow of pedestrian and vehicular traffic is maintained at all times

[10] Based on the OCMC comments, the research team reviewed the following site http://streetworksmanual.nyc/chapter-three/permits-and-approvals which has information about the work zone permits/approvals but did not have the type of formal organizational chart with key personnel that was mentioned in this report.
[11] Based on the comments received from OCMC on March 2017.
[12] Based on the interview with NYCDOT Sidewalk repair and management on November 2015.

10. Special Events	Special Events Unit is involved in the process.	The Mayor's office provides permits for street events. Games (super bowl): coordination with other units to embargo permits temporally. Special events information is integrated with NYCSTREETS.	N/A	No modelling is usually necessary in these cases.	N/A	HIQA may inspect emergency street openings/excavations and utility access cover openings.

Work Zone Coordination by NYCDOT

Based on the current interviews conducted, the team developed a sketch of the usual information flow that occurs before a work zone is initiated, including major decision points and documentation processes that produce a database. This workflow is shown in Figure 23.

The comments of OCMC about the initial interview with OCMC indicated that currently there is an organizational chart of NYCDOT divisions geared towards work zone coordination such as identification of responsible divisions, management and dissemination of information, and relationship and hierarchy between the involved divisions. However, this information is not available to research team and cannot be added to this document. The research team intends to work with OCMC in the next phase of this project to obtain the aforementioned documents if they can be made available for review and questions. The workflow within NYCDOT, prepared based on the information provided in the interview, is depicted in Figure 23.

Although each division has its priorities for work zone coordination, there are internal coordination efforts between divisions in terms of regular meetings to ensure coordination as per the comments of OCMC. For example, there are monthly utility, DOT resurfacing meetings and weekly schedule is sent to OCMC and NYCPD[13].

Each division has its own database to keep track of the ongoing projects, as indicated in Table 4. However, all permits for street work are tracked in NYCSTREETS with the objective of coordinating and planning the time and the order of the actual occurrence of the work[14].

For large projects, such as capital projects, traffic modeling is being conducted to estimate their impacts on traffic. However, for other types of projects, such as the ones also managed by OCMC and Roadway Repair Division, which outnumber the capital projects, the impacts are determined by OCMC project managers.

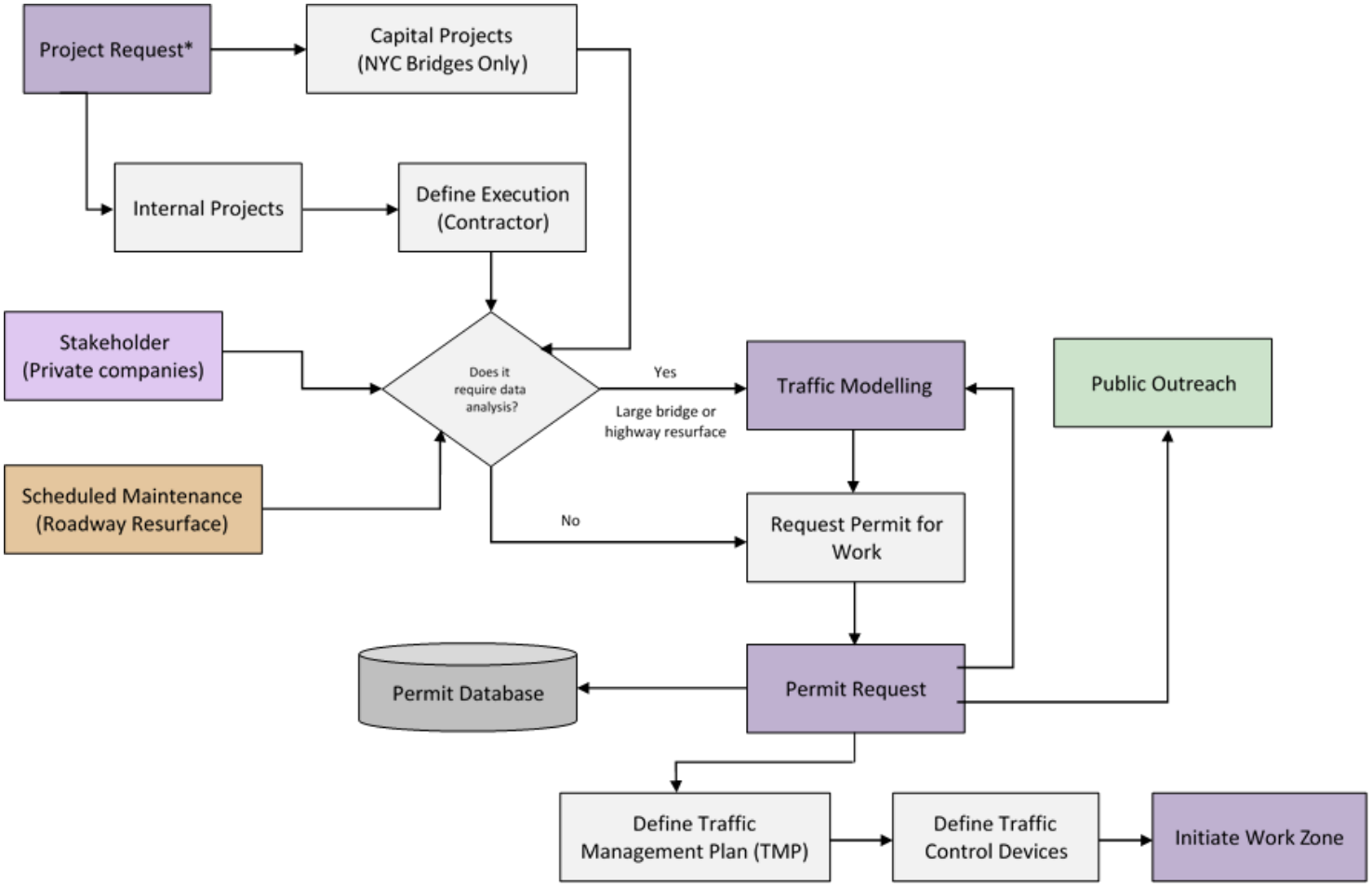
It was discussed during the interview that charts for determining h[15]ow many lanes should be closed based on the impact of the work zone would be useful.

One of the questions included in our interview was “What is the impact of Vision Zero and recent safety concerns in the development of strategies to coordinate work zones?” In response to this specific question, the research team was told that main focus of the work zone activities is pedestrian activity – projects are instructed to prioritize their movements.

[13] Based on the comments received from OCMC on March 2017.
[14] Based on the comments received from OCMC on March 2017.
[15] Based on the comments received from OCMC on March 2017.

Work zone requirements may include suggestion of schedules off-peak hour, or equipment for both worker and pedestrian safety.

In the case of coordination during special street events such as street festivals, farmers markets, and parades, permit from the Mayor's office Street Activity Permit Office (SAPO) and/or city's other supporting permitting agencies is needed (39). These special events' locations are flagged in NYCSTREETS and their information and issued agencies are provided to OCMC's weekly report that goes out to press, other agencies, utilities and industry coordinators.



*DDC road, water and sewer construction is not done with DOT

Figure 23: Workflow of NYCDOT Divisions Involved in Work Zone

As far as public information is concerned, in addition to coordination with the traffic management center and utilization of electronic message signs, NYCDOT also utilizes temporary signage in some areas to warn the public about the work zone and divert traffic if necessary. Also, an existing e-mail list and meetings are used to notify the community regarding street closures. Most complaints from the public go to NYCDOT. Some are directed or shared with other agencies or authorities if it is in regards to their actual construction work.

Key Points from the NYCDOT Interview

The research team identified the key points listed below that might be useful for improving the current work zone coordination practice at the NYCDOT.

- There is a need to expand the NYSTREETS database across the NYCDOT for managing the status of ongoing and planned projects that are not currently part of this database. This expanded database should include data from all agencies (including NYC Dept. of Buildings), utilities and smaller private work sites (active and planned). This database can then be called as the "unified database". The creation and maintenance of this "unified database" can be achieved by implementing an online tool that will allow "all parties" to enter at least basic information (location / date / duration / etc.) that can be saved in the unified database mentioned above. This will be an important improvement compared to the current practice where each division has its own database and utilize different tools to store project information.

- As per the comments of OCMC, a tool with the above functionalities does not currently exist. DOT IT&T is working on a capital projects tracking application, "Pavement works", which can be a platform for "unified database". It will become operational in 2018[16].

- As part of this phased approach to building a new tool, a web-based on-line spatial mapping capability for each location to allow automatic interaction with legal permit data tracking and various activities at other construction sites can be a useful feature. One of the key aspects of this effort will be to link City's and State's GIS maps and systems. This will enhance collaboration and coordination within NYCDOT as well as with outside agencies such as TRANSCOM and Mayor's office among others.

[16] Based on the comments received from OCMC on May 2017.

- As noted by the OCMC, modeling to estimate the impact of long-term and significant projects can still be done separately on an as needed basis as it is done currently until a more robust tool described above is developed and deployed. However, as one of the final steps of the development efforts of this tool, a simpler and robust traffic impact analysis capability can be added to quantify impacts of short duration and minor roadway repair and utility projects. This can help the decision makers to have a quick idea about possible impacts of these relatively minor projects that occur quite frequently in NYC.

TRANSCOM

The Transportation Operations Coordinating Committee (TRANSCOM) is a coalition of 16 transportation and public safety agencies created to provide a cooperative, coordinated approach to regional transportation management (38). TRANSCOM is not involved in the process of requesting and operating work zones, but play an important role of coordinating work zones at a regional level.

TRANSCOM holds an annual meeting including several agencies in tristate area to discuss the calendar and future projects to be executed in the next year. In December, TRANSCOM sends the agencies the project coordination database to be updated and reviewed for the next calendar year. In this process, utility work and special events are not included, but they are discussed in the meeting itself. The meeting is usually conducted in March/April, where the updated database is discussed and reviewed with the participation of the main agencies that together identify potential conflicts and disruptions in main corridors.

TRANSCOM is responsible for creating a report and maintain an online version of the database of the construction projects, in the OpenReach platform.

OpenReach is a web-based, multi-modal, regional (NY/NJ/CT) inter-agency tool that (39):

- Links dozens of transportation and police operations centers
- Provides direct access for decision makers
- Integrates incidents/construction/travel times/video
- Includes variable message signs/HAR
- Serves as database for travel info systems (e.g. NJ 511 System)

It includes three independent but integrated systems of TRANSCOM Region, New Jersey Statewide and Delaware Valley Regional Planning Commission (DVRPC). OpenReach is used by the Traffic Management Centers in New Jersey for their

daily traffic management activities. It includes not only active and dormant work zones in the state but also work zones in the TRANSCOM database, and also includes incidents and infrastructure assets. OpenReach includes all events including information on historical work zones such as the time and date of work zone, how many lanes closed, the description of work zone and type of project.

The agency review the projects in OpenReach and help requesting real-time information and variable message sign (VMS) needs for the main projects, reaching to local agencies and providing communication between agencies to coordinate the construction work.

Also, TRANSCOM have an Individual Agency Coordination Effort with the NJDOT, in the form of task force where monthly meetings and weekly phone calls are conducted to coordinate projects. As stated before, TRANSCOM also provides help with public outreach, coordinating VMS signs and real time information in the corridors during incidents or planned work.

The TRANSCOM interview is summarized in Table 5.

Table 5: Summary of TRANSCOM Interview

1. Main Role	Improve cooperation between agencies
2. Characteristics of Work Zone	Involved in regional planning, not final responsible for work zones
2.1. Duration	Long - regional level
2.2. Typical Work Zone	N/A
3. Database	Open Reach database maintained and updated by agencies under supervision of TRANSCOM
4. Guidance and Procedures	Uses online mapping system, guidance manual, and incentives to improve coordination with utility companies, contractors, and agencies
5. Institutional Coordination (Intra-agency)	Focused on multimodal coordination
6. Public Outreach	Contacts different agencies when VMS coordination is needed. Provide real-time information about travel time in places where work is happening.
7. Modeling	Not responsible for modeling impacts
8. Coordination	Promotes an annual meeting (March/April) for discussion of upcoming roadway projects managed by different agencies.
8.1. Management and partnerships	Produces a report listing upcoming construction zones and possible conflicts to be discussed in the meeting. Every

	agency in the meeting is responsible to sharing requests of projects in the Open Reach system. Individual task Force currently with NJDOT - weekly calls and monthly meetings to coordinate projects.
9. Safety Concerns	N/A
10. Special Events	Response to incidents - lane closures and weather events.

Work Zone Coordination by TRANSCOM

Based on the current interviews conducted, the team developed a sketch of the usual information flow within TRANSCOM for coordinating work zones. This workflow is shown in Figure 24.

As mentioned above, TRANSCOM does not request or operate work zones, instead it helps create strategies and improve coordination efforts between agencies. The importance of this agency is the fact that it reaches different regional stakeholders that are significantly involved in the planning process for road construction.

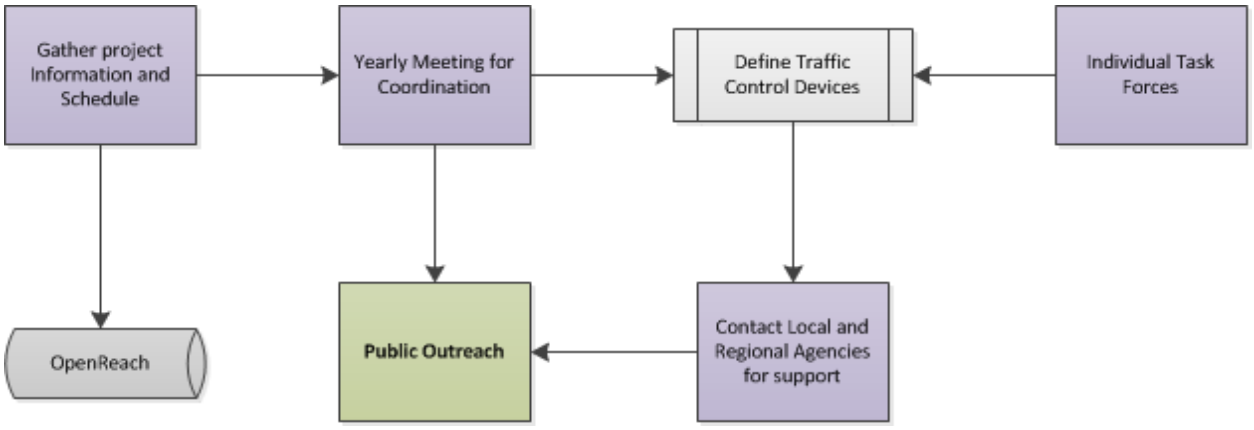


Figure 24: Workflow of TRANSCOM Work Zone Coordination

Their efforts on coordination are significant and very important for the goals of the project. Since their hold the support and investments in the main work zone database (OpenReach) in the tristate area, the scheduling process can be implemented in cooperation with this agency in the future, in one of the annual meetings or as an integrated functionality of the current database.

It should be mentioned that TRANSCOM's role is not only limited to work zones. They play a major role in coordination during unexpected events such as a major

accident or a weather event. As a recent example, in the case of an overturned truck on August 4, 2014 that led to the closure of New Jersey Turnpike in both directions, TRANSCOM coordinated with different agencies such as MTA, NYCDOT, NJ TRANSIT bus, PANYNJ and also bus companies such as Lakeland, Peter Pan and others, and coordinated with the police force to alleviate the impact of the accident. The effort extended as far as coordinating with the cargo companies, utilizing VMS messages by contacting Pennsylvania Turnpike Commission, Philadelphia DOT, Delaware DOT, Maryland DOT, and cancelling construction work where necessary.

As mentioned earlier, OpenReach is the central tool used by TRANSCOM to manage, plan the ongoing and planned work zones in the tristate area. As far as public information is concerned, TRANSCOM conducts public outreach via VMS, 511.org and 511ny.org.

Based on the interview, it was clear that although TRANSCOM is the key agency in coordination of major work zones and events within the tristate area, short term strategic goals should also be considered, such as short term roadway projects that do not necessarily require traffic impact analysis or discussed during the yearly meetings due to their less important nature. It was discussed during the interview that a computer tool would be of great use to demonstrate the impact of coordinating versus not coordinating projects, and to assess the impact of simultaneous projects.

Key Points from the TRANSCOM Interview

The research team identified the key points listed below based on the interview with TRANSCOM.

- TRANSCOM plays a major role in coordination of significant and long-term projects and unexpected events within the tristate area. Their work flow during these events should be carefully investigated and applied for the proposed NYCDOT work flow, where necessary.
- TRANSCOM utilizes OpenReach tool for providing time sensitive information about the ongoing and planned work zones and other events in the tristate area. NYCDOT should benefit more from the already available tool, namely Work Zone Coordination Tool; developed by NJDOT which utilizes the OpenReach database.
- Currently, TRANSCOM is playing a key role in the coordination of long-term projects with key players like OCMC by providing weekly and often daily updates. Moreover, coordination of the short-term projects is also important and can be beneficial to NYCDOT/NYSDOT in the future.

Port Authority of New York and New Jersey

The Port Authority of New York and New Jersey (PANYNJ) builds, operates, and maintains critical transportation and trade assets. Its network of aviation, rail, surface transportation and seaport facilities annually moves millions of people and transports vital cargo throughout the New York/New Jersey region. Figure 25 demonstrates the facilities that are in the current domain of PANYNJ.

Figure 25: Overall area of interest and facilities operated by PANYNJ (40)

Among many facilities that PANYNJ operates, the most relevant ones for this research project are the bridges and tunnels, and terminals.

Bridges and Tunnels

PANYNJ is responsible for Bayonne Bridge, Goethals Bridge, George Washington Bridge, Holland Tunnel, Lincoln Tunnel and Outerbridge Crossing. These are major crossings between New York and New Jersey, and have a high daily volume of vehicles. Any construction projects related to these are usually capital projects or scheduled maintenance projects.

In the first case, construction projects are part of Capital programs, requiring several studies and preparation beforehand of the execution of the projects. PANYNJ have an in-house team that provides modeling know-how to execute these studies, including a design engineering team that takes part in the planning process. In some cases, outside contractors are needed to help with this scope of the work due to the significance of some projects.

For the maintenance projects, the request usually comes from the Facility division, which provides inspections of bridges and determine actions to be taken to promote safety operations. The bridges are annually inspected, generating a report with priority levels of repairs and maintenance.

In both cases, PANYNJ includes other agencies in the process of planning and executing the construction, since the facilities are major corridors in the City, and their closures have direct impact on the transportation network. The agency also needs to coordinate permits for executing work and placing equipment at adjacent roads. These permits are issued either by NYCDOT or NJDOT.

PANYNJ provides public information about the ongoing projects happening at its bridges and tunnels. Its website contains detailed information about the work being executed, including time, duration and reasons for closing its bridges / tunnels. Also, the agency operates different social media accounts to improve communication with the users, allowing fast exchange of information in case of incidents. Using social media such as its Twitter (https://twitter.com/PANYNJ) or e-alert website (www.PAalerts.com), the agency provides real-time information to users, including traffic conditions and alternative routes.

Terminals

PANYNJ is also responsible for managing some terminals in the City, e.g. PATH, PA Bus Terminal, JFK Airport, LaGuardia Airport and Newark Airport, plus the air trains connecting the airports to the main lines operated by MTA. These airports are some of the largest in the world in term of passenger traffic, and the PATH Bus terminal operates lines that connect New York City to New Jersey in a local and regional level.

In cases of construction that affect transit operations, the construction and maintenance projects have a bigger impact on passenger, also creating additional traffic in the streets due users shifting to driving to their destinations. This is very noticeable in the presence of special events, where PANYNJ needs to coordinate traffic in these terminals to accommodate the unusual demand for passengers.

The PANYNJ interview is summarized in Table 6.

Table 6: Summary of PANYNJ Interview

1. Main Role	Manage infrastructure (bridges, tunnels and terminals)
2. Characteristics of Work Zone	Bridge/Tunnel constructions zones and repairs can vary from small inspections to full closure
2.1. Duration	Long term projects
2.2. Typical Work Zone	Bridge/Tunnel repairs, usually creates bottlenecks and require special attention.
3. Database	Track of projects done using a spreadsheet. Traffic Management Plan (TMP) – that contains information such as lane closure or diverting capacity is a one-page document per project
4. Guidance and Procedures	Requirements issued by permits - have 4 staff members allocated to deal with permits. Permits for NYSDOT on state highways, NYCDOT and NJDOT are different.
5. Institutional Coordination (Intra-agency)	Different groups: Design, ITS, quality control, operations are all working together. Quality and insurance division provides inspections in bridges detailing needs for repairs and maintenance. Facilities usually are the team that kicks-off projects.
6. Public Outreach	Bridge and Tunnel alerts. Social Media presence (twitter accounts) - inform passenger traveling.
7. Modeling	PA has in-house knowledge for developing models and simulation for construction projects - usually required based on the importance of projects. Modeling software such as Synchro, Visum/Vissim, Aimsum are used.
8. Coordination	Require meetings with DOT for planning impact on parallel corridors and major streets in neighborhood. Coordinate projects with TRANSCOM.
8.1. Management and partnerships	Not involved in some minor daily operations. Considering implementing a tool for coordinating work zones in-house.
9. Safety Concerns	N/A

10. Special Events	Synchro analysis is done when needed. Operations of PATH is affected in some cases.

Work Zone Coordination by PANYNJ

Based on the interview conducted, the team developed a sketch of the information flow within PANYNJ for coordinating work zones. This workflow is shown in Figure 26.

The interview indicated that PANYNJ does not utilize an official database, but uses a simple spreadsheet to keep track of projects. This is due to the nature of projects, which are usually long-term and significant, requiring a full-fledged traffic impact study and the involvement of different divisions within PANYNJ, and other agencies.

Each project is initiated with the facility inspection, which recommends the schedule for maintenance. Next, an engineering and design unit is responsible for the traffic impact study and traffic management plan (TMP), also providing requirements for requesting a permit from the correspondent agency. A full impact report is prepared if the proposed project is expected to have a significant impact on the traffic and the community. Finally, other teams are involved to follow up with side tasks, such as public outreach and equipment placement that are defined according to the project needs.

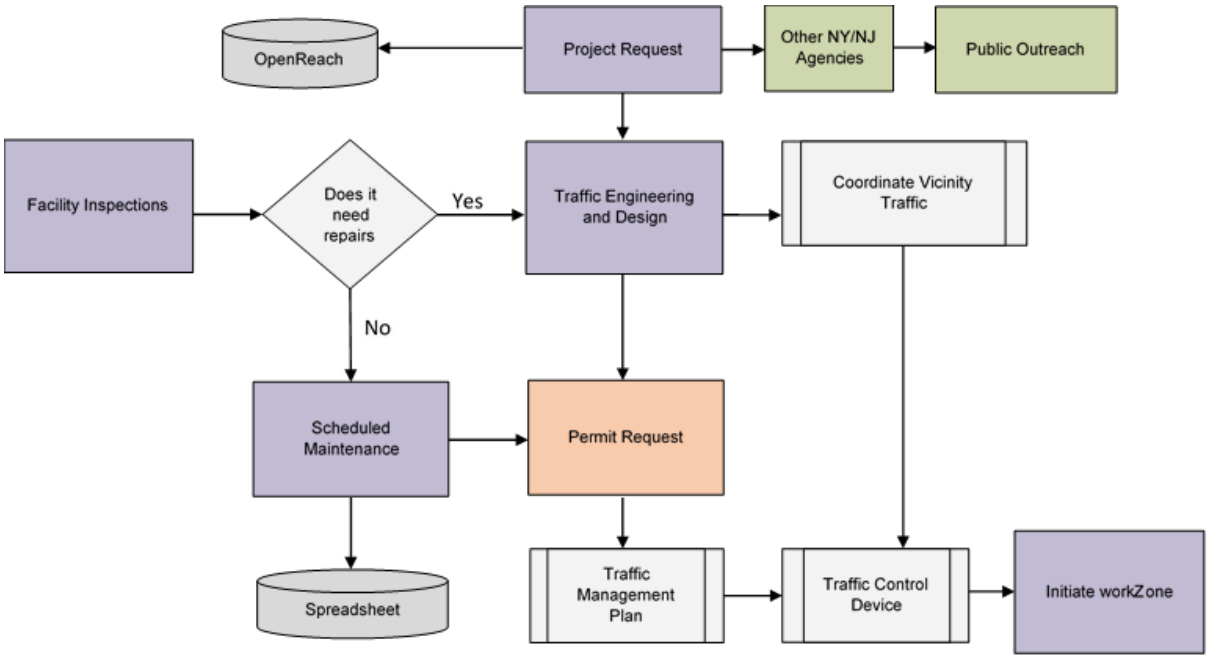


Figure 26: Workflow of PANYNJ Work Zone Initiation

PANYNJ has a traffic engineering design, intelligent transportation systems (ITS) and operations groups that may have a task related with a work zone needed for the specific project. PANYNJ conducts traffic impact analysis for their projects. Traffic analysis approach is not unified and varies from one project to another. Microscopic traffic simulation tools, such as Aimsun, Vissim, Synchro, or spreadsheet tools such as QuickZone can be used, depending on the nature of the project. Some traffic impact analysis is done in-house, some are contracted to outside consultants.

Some of the projects that PANYNJ is responsible do not follow the pattern described above. For example, when a bridge requires emergency maintenance or repair, the planning process usually cannot be completed with the level of detail specified above. Such cases are classified as emergency response management more than work zone management.

Also, it is important to indicate that the agency relies on other agencies such as NYSDOT, NYCDOT, NJDOT and TRANSCOM. In the case of bridge work, the impact can be extended to streets which are in the domain of the city or a state agency, requiring a good communication between all the agencies before implementation. Again, as these projects are likely to last for years, the planning process requires a long time and a coordinated effort.

PANYNJ website includes the details of all capital projects within the next 10 year (41). The agency reaches out the public via TRANSCOM, and also through their website and their social media accounts.

Regarding special events, the agency plays a very important role, since it has under his responsibility three area airports, and the PATH – which connects NYC to NJ. Special Event Coordination is an important topic for the PANYNJ. Thus, PANYNJ certainly can be one of the agencies with more interest than others that are interviewed in adopting a scheduling software that can help improve coordination and visualization in this area.

Key Points from the PANYNJ Interview

The research team identified the key points listed below based on the interview with the PANYNJ.

- PANYNJ undertakes long-term and significant projects involving bridges, tunnels and airports. Any work involving PANYNJ facilities requires utmost attention since any disruption of traffic flow at these facilities might lead to congestion at the wider network level.
- PANYNJ does not currently use any official database to track the ongoing and/or planned project work zones.
- Because most of their projects are significant in terms of time and facility type, TRANSCOM plays a major role in coordinating their work zones.

- PANJNY is interested in using a scheduling software that can help improve coordination during special events.

Metropolitan Transit Authority – NYC Transit

The Metropolitan Transportation Authority (MTA) operates the subway, buses, and railroad in New York City, Long Island, southeastern New York State and Connecticut (42). Also, MTA operates bridges and tunnels in New York City.

New York City Transit (NYCT)

NYC Transit is a division of MTA that manages the subway and buses in the five NYC's boroughs, accounting for 80% of the city's surface mass transportation (42). NYCT does not own the infrastructure besides the buses and subways carts that operate in the streets and trails that belong to other agencies. Because of that, a strong coordination with other agencies, particular NYCDOT is established in order to maintain their service and operations.

Most of the work zones that concerns NYCT are responsibility of NYCDOT, and the involvement of NYCT is restricted to advisory regarding transit operations above the ground. The most common case is when NYCDOT need to issue a permit for a construction work that will affect any of the bus lines managed by NYCT: the coordination between the agencies allow that NYC DOT's OCMC is necessary beforehand the permit is issued to certify that no bus stops or lines will be interfered, and in such cases, what are the changes in the bus operations that needs to be addressed.

An important detail is that NYCT has to contract NYCDOT Transit bus stop signs division for executing some of the work, since the infrastructure is under their domain. When this happens, DOT has a 45-day windows to respond and execute the services provided, such as sign placement, bus stop repairs and other minor jobs. Therefore, all the databases that concern this project are responsibility of NYCDOT, having NYCT only managing current requests. NYCDOT shares the database in a read-only format when requested or needed.

Coordination with TRANSCOM is also a key point for NYCT, where the collaboration is focused on exchanging data about projects and events that may change the regular bus schedule. TRANSCOM focus on the outreach for other agencies and facilitates the cooperation between the agencies when special services are needed, and this works both ways: while TRANSCOM may notify NYCT of constructions and events that may impact current NYCT routes, it may also request help for supplying a special demand, in cases as weather events and most recently the NJ Transit Strike in March 2016.

When changes in schedule or routes operations are necessary, NYCT takes responsibility on the public outreach along with other agencies. Their website http://www.mta.info/nyct provides detailed information of real-time service status of subways and bus lines, and also future service changes and other information for commuters. Also, the app BusTime provide same real-time information for users of the transit system, and other mapping app available can provide good quality information. Last, when major changes are required, coordination with community boards and email list are used to improve the communication.

Since NYCT does not provide any traffic operations in its own infrastructure, no tools for planning construction work is needed. The only tool that the agency uses is HASTUS, which is a commercial software that helps optimize the routes and schedules for buses, and it is run in a quarterly basis. Demographic data and land use are also observed when changes in routes and schedules are needed.

Safety Programs in NYC have a big impact on the bus routes and the network. Since the launch of Vision Zero, a lot or redesign of streets have been observed and have impacted some bus routes. NYCT notes that bike lanes causes some conflict with bus routes which need special attention when designed. Also, right turn bans and curbside improvements have been forcing NYCT to create different strategies and resign stops and routes. In terms of safety improvements adopted by NYCT, the agency has been pushing towards the adoption of Collision Avoidance System in their fleet, which can improve safety conditions around the buses for pedestrians and bikes. Some pilots have been conducted in this area recently, but further settings are being studied in order to have a full implementation of the system. Other technologies to improve safety are also being considered, such as USB ports, WiFi and LED screens.

One of the key roles of NYCT is the special events coordination. Since NYC is a transit oriented city, when special events happen the agency needs to improve and provide a service that is compatible with the demand expected. In all the cases, the permits and planning process are handled by the Mayor's Office, and NYCT is contacted to create a reroute plan and provide additional services for these events. NYCT cooperates with each borough police department to help coordinate the entrance in stations, parking and curb space utilization. For big events, the agency issues memos to be distributed to other agencies and public, and in special cases a book is produced with detailed information of the coordination process and strategies used for management.

Key Points from the MTA NYCT Interview

The research team identified the key points listed below based on the interview with the NYCT:

- NYCT is not directly involved in the planning or execution of work zones. Their work is strictly related to adapting to construction areas that provide additional services or reroutes of the current buses traversing work zones.

- NYCT does not hold a database in-house that serves for the purpose of this project. Instead, they share information with NYCDOT and TRANSCOM.
- NYCT is pushing forward the application of Collision Avoidance System in their fleet in order to comply with Vision Zero Program.
- NYCT plays a fundamental role in the special event coordination, working directly with borough's police department to provide effective services in such cases.

New York City Department of Design and Construction (NYCDDC)

The New York City Department of Design and Construction is acted as New York City's primary capital construction project manager. It has two divisions: Public Buildings and Infrastructure. It provides communities with new or renovated structures such as firehouses, libraries, police precincts, courthouses, senior centers and more (43). The main purpose is to ensure highest quality of city's public buildings and infrastructure, which are designed and constructed safely, expeditiously and economically]. NYCDDC collaborates with other city agencies, as well as with emerging and world-renowned architects and consultants to create and maintain progressively designed projects that support current and future generations, and which foster the key municipal goals of growth, equity, sustainability, resiliency and healthy living (44).

DDC provides designs and executes the constructions using in-house engineers and consultants. Usually, around 80 projects are going on simultaneously. Project duration varies from 3-6 month (i.e. resurfacing project, redesign of intersections) to 10 years (i.e. Times Square project).

Work Zone Coordination by NYCDDC

Typical work zone projects involve roadway construction, sewage and water main replacement. NYCDDC coordinates with several agencies and partners during the project cycle. For example, the agency cooperates with utilities to avoid open street that were just reconstructed. NYCDDC has a constantly updated list of contacts of other agencies and partners.

Impact of projects from NYCDDC or other agencies in nearby or parallel corridors are taken into consideration to make sure that no two major projects happen in the same area at the same time. Traffic simulation models are considered for estimating traffic impact during construction phase, yet sometimes they are difficult to implement due to the complexity of the project. For instance, it is very hard to simulate what is happening for Times Square project because of its extensive high pedestrian volume, traffic and political importance. No specific model is being used for design. NYCDDC also holds internal alignment meetings to discuss projects and to avoid potential conflicts between projects.

It is indicated that no official workflow chart has been used for the agency, however based on the interviews, the team built a sketch of the usual information flow (**Figure 27**) for NYCDDC project process.

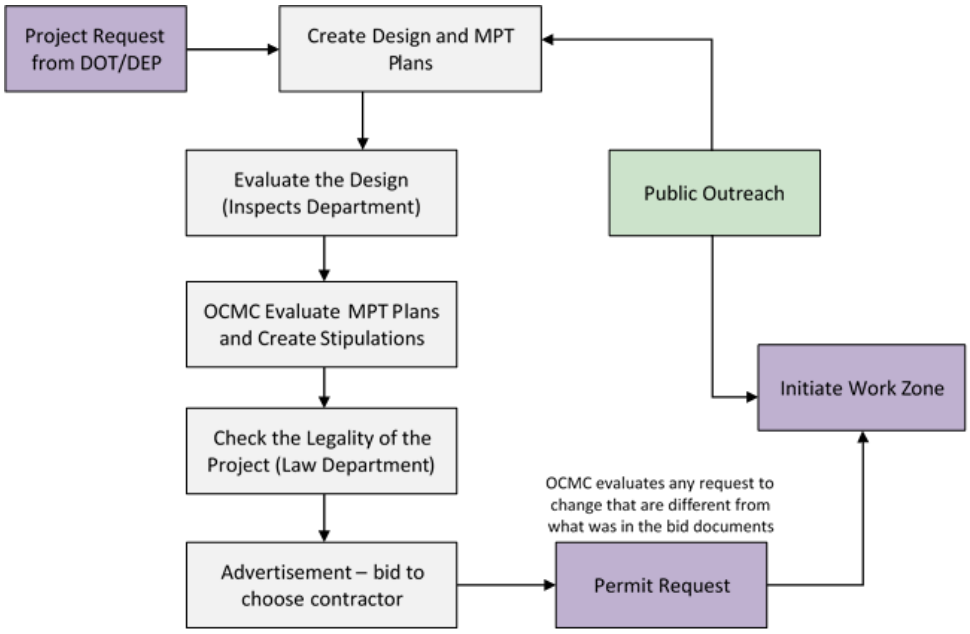


Figure 27: Workflow of NYCDDC Work Zone Initiation

Another highlight of NYCDDC's role is that the agency takes the responsibility of public outreach through the entire project. NYCDDC sends introductory letter to public general, state DOT, community Boards, City Agencies, Utility informing about the projects. During design phase, projects are discussed over Community Board Meetings with communities. During construction phase, community liaisons updates contractors and NYCDDC about community complains, including noise, dust, disturbance of work zones.

Table 8: Summary of NYCDDC Interview

1. Main Role	Provides designs and executes the constructions for New York City's capital construction projects
2. Characteristics of Work Zone	Provides designs and Maintenance and Protection of Traffic (MPT) plans for review and approval from NYCDOT-OCMC
2.1. Duration	Both short term and long term projects
2.2. Typical Work Zone	Roadway resurfacing, sewage and water main replacement

3. Database	No publicly available database that can be shared with research team exists at this point. However, as per the comments received from OCMC, they have such a database.
4. Guidance and Procedures	• Coordinate with OCMC to finalized the MPT plans • Need to apply permits from OCMC • Provide official guidelines (Design Consultant Guide 2016) to consultants
5. Institutional Coordination (Intra-agency)	Conduct internal meetings to discuss project priorities. GPS unit identify project conflicts for the agency.
6. Public Outreach	Sends Introductory Letter to public general/state DOT/community Boards/ City Agencies/ Utility informing about the projects. Have full contact with communities: 1) Discussed with communities via community board meetings during design phase. 2) Community liaisons updates contractors and NYCDDC about community complains– noise, dust, disturbance of work zones.
7. Modeling	No models are used during design phase. Simulation models are considered for construction phases, but are not always applied due to the complexity of some projects.
8. Coordination	Conduct meetings with utilities and CPI group in NYCDOT to discuss project and potential conflicts. Coordinate with OCMC for permits and MPT plans. Interested in having a visualization tool of all projects.
8.1. Management and partnerships	MPT created by NYCDDC indicates preferred Traffic Temporary Control Devices and contractor is responsible in installing signs and barriers.
9. Safety Concerns	Most of the projects executed by DDC today are related to Vision Zero. NYCDOT puts Temporary barriers for some projects before the final design of the projects.
10. Special Events	N/A

Key Points from the NYCDDC Interview

The research team identified the key points listed below based on the interview with the NYCDDC:

- NYCDDC receives majority of the work zone projects from NYCDOT for roadway and New York City Department of Environmental Protection (NYCDEP) for sewage and water main.
- NYCDDC's provides designs and executes the constructions using in-house engineers and consultants. Their funding source comes from other agencies in the city.

- NYCDDC does not use any official database to track the ongoing and/or planned project work zones, instead, internal meetings are scheduled to avoid conflicts of NYCDDC's project.
- Coordination with several agencies/partner during the project cycle
- NYCDDC acts actively in public outreach

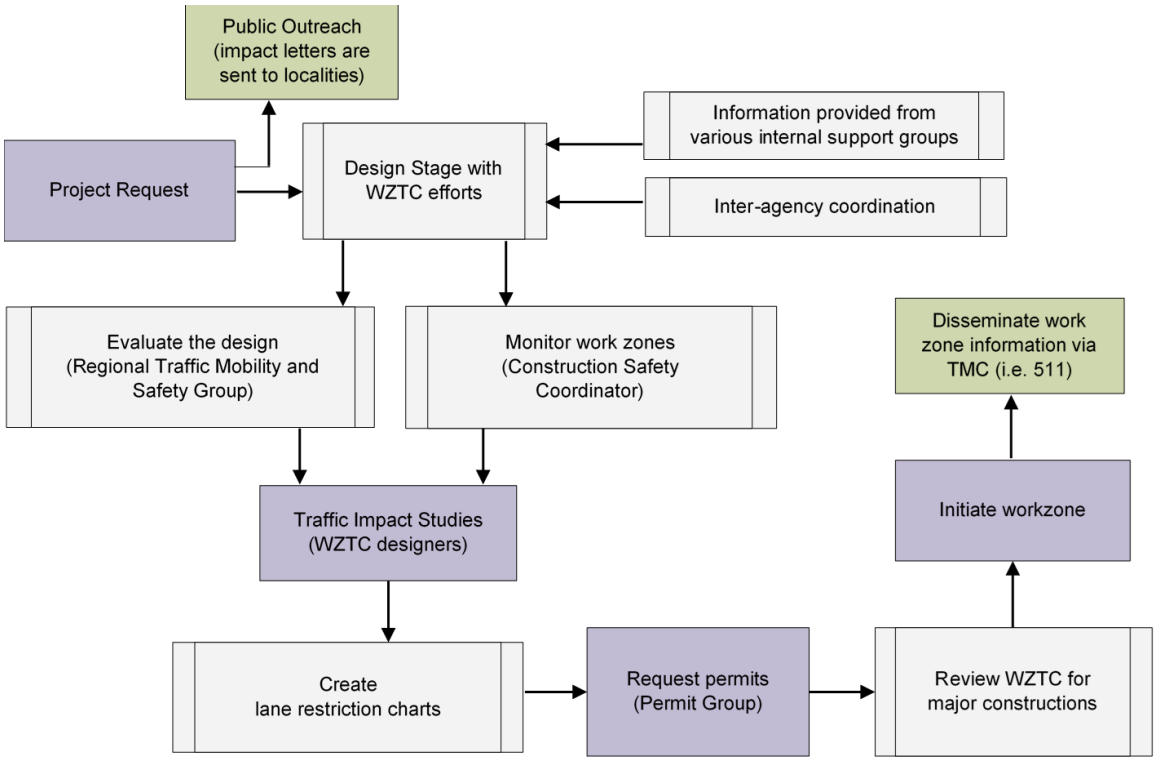
New York State Department of Transportation (NYSDOT)

NYSDOT coordinates and assists in the development and operation of a safe and durable transportation system including highways, railroads, mass transit systems, ports, waterways and aviation facilities. The agency concentrates on administering public safety programs for railroads and motor carriers engaged in intrastate commerce and providing oversight in matters relative to the safe operation of other mode such as mass transit system (45).

NYSDOT Region 1 (Albany)

NYSDOT Albany office (Region 1) is one of the regional offices that serves approximately 1 million residents and maintains 5,300 highway lane-miles and 828 state bridges (45). The people of Region 1 construct mainly highway projects that entail pavement / bridge rehabilitation and reconstruction, guiderail, signing, and striping. Maintenance crews conduct minor highway and bridge repair, as well as other maintenance functions such as plowing and off-road clean up. NYSDOT plays a key role in work zone coordination for the projects with regional traffic impact.

Based on the current interviews conducted, the team developed a sketch of the usual information flow within NYSDOT Region 1 for coordinating work zones. This workflow is shown in **Figure 28**



.

The interview indicated that NYSDOT Region 1 does not utilize an official unified database, but a list of current construction projects that provides contact information is used to stay aware of current sites. The planning department also provides a 5-year program for upcoming projects, schedule sometimes changes depending on other variables.

NYSDOT Region 1's current system relies on experienced Work Zone Traffic Control (WZTC) designers from the Design Review Unit of the Traffic Safety and Mobility Group in conjunction with the Construction Safety Coordinator to monitor work zones under construction. NYSDOT Region 1 follows the basic constraints of scheduling work zones; weather (wet/dry and temperature), material delivery (including equipment rental), utility conflicts/coordination, event conflicts, seasonal/tourist conflicts, adjacent projects, and cost. In addition, basic lane closure restriction parameters are followed as well to create lane restriction charts that window traffic impact outside peak traffic flow. Those restriction parameters include thresholds of 1500 veh / lane / hour for high speed multi-lane facilities (Interstate), 1200 veh / lane / hour for high speed multi-lane highways with signals, and 650 veh (combined both directions) for two lane roads.

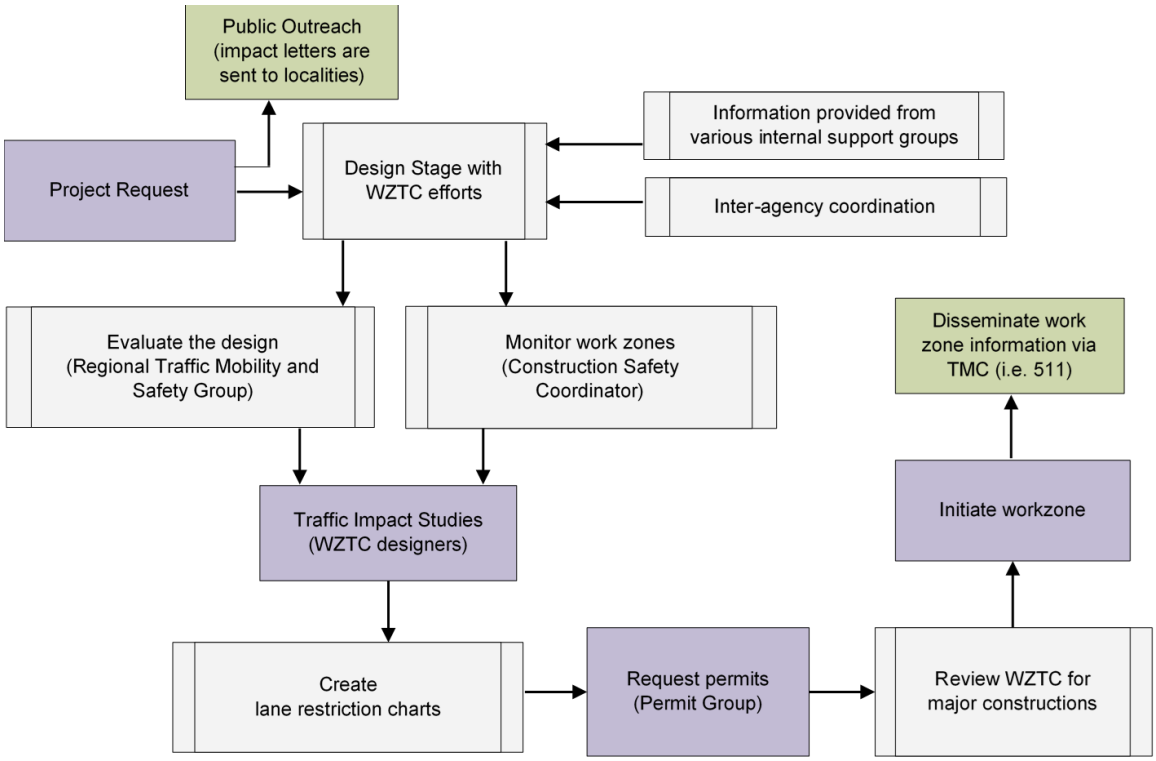


Figure 28 Workflow of NYSDOT Region 1 Work Zone Coordination

It was discussed during the interview that some of the programs that are designed to help quantify queues and delays for work zones are tested but they are not always applied due to the complexity of some projects. For example, low volume situations are ignored because the user cost doesn't register under such situations, which can be an issue with rural populations.

The NYSDOT Region 1 interview is summarized in Table 7.

Table 7: Summary of NYSDOT Region 1 Interview

1. Main Role	Provides designs and executes the constructions for New York State's regional construction projects
2. Characteristics of Work Zone	Mainly highway projects, include many highway bridges
2.1. Duration	Both short term (i.e. off-road cleaning up) and long term projects (i.e. bridge rehabilitation)
2.2. Typical Work Zone	Pavement/bridge rehabilitation and reconstruction, guiderail, signing, and striping
3. Database	No database is used, but a list of current and upcoming projects in 5 years is provided annually

4. Guidance and Procedures	• Utilizes the Regional Traffic – lead effort for years • Have a group that helps coordinate state requirements for new construction permit, formalizing the roles and responsibilities of each involved parties to ensure minimal traffic impacts. • If the construction zone is in New York City, all state construction work requires a NYCDOT OCMC work permit after MPT review.
5. Institutional Coordination (Intra-agency)	Work Zone Traffic Control (WZTC) efforts are typically coordinated by the Regional Traffic Mobility and Safety Group, but they are provided information from various internal support groups such as planning, real estate, materials, survey, etc. in the design process.
6. Public Outreach	Prior to the start of a project, impact letters are sent to localities warning them of upcoming work, and providing information and contacts to the affected public. Public complaints can be posted via internet based webpage and are answered by the in-house design team and / or Construction personnel, depending on the topic.
7. Modeling	No sophisticate modeling method is used. Mainly rely on experienced WZTC designers, who utilize basic lane closure restriction parameters to create lane restriction charts that window traffic impact outside peak traffic flow.
8. Coordination	Other agencies are typically involved if they own the system NYSDOT are working on or near.
9. Safety Concerns	Coordinates a formal annual work zone review to independently look at all types of work zones and rate their performance. WZTC effort are put into the design stage for over 15 years to understand and minimize traffic impact from Scoping to final design, which is the basis of NYSDOT Driver's First Initiative (48).
10. Special Events	The event permits are also coordinated out of the Regional Traffic Safety and Mobility group, which coordinates with the WZTC designers to include all potential event conflicts in with the daily and holiday restrictions to be included in the contract plans.

Work Zone Coordination by NYSDOT Region 1

Work Zone Traffic Control (WZTC) efforts are typically coordinated by NYSDOT's Regional Traffic Mobility and Safety Group, but they are provided information from various internal support groups such as Planning, Real Estate, Materials, Survey, etc. in the design process. Other agencies are typically involved if they own the

system we are working on or near, such as the Office of General Services (OGS) which manages the Empire State Plaza and the State Office Campus, both of which have adjacent highway systems with pavement and structures. Early coordination is essential, with hopefully one entity in charge of coordinating the combined effort.

Other agencies are typically involved if they own the system NYSDOT are working on or near, such as the Office of General Services (OGS) which manages the Empire State Plaza and the State Office Campus, both of which have adjacent highway systems with pavement and structures. Early coordination is essential and effective, with hopefully one entity in charge of coordinating the combined effort. But all state construction work requires a NYCDOT work permit after MPT review.

Regarding safety concerns, NYSDOT coordinates a formal annual work zone review to independently look at all types of work zones (Construction, Maintenance, Permit, etc.) and rate their performance. From that, they review concerns with the appropriate parties and determine talking points for future WZTC safety and instruction efforts. WZTC effort has also been putting into the design stage for over 15 years to understand and minimize traffic impact from scoping to final design, which is the basis of NYSDOT's Driver's First Initiative program. The only change is the final decision making, which has leaned away from "share the pain" to "try and avoid most impact".

As far as public information is concerned, NYSDOT Region 1 utilizes the Transportation Management Center (TMC) that keeps a comprehensive list of all active construction, maintenance, and permit projects, to disseminate information out to the traveling public. TMC uses active feeds from live cameras as well as information sent by each project to help "monitor" all active work, both planned and incident related. TMC information is available on multiple fronts, including 511, to meet the needs of public in terms of real time traffic information and condition reports. Any complaints from public is directed to in-house design team and / or Construction personnel, depending on the topic.

Key Points from NYSDOT Region 1 Interview

The research team identified the key points listed below based on the interview with the NYSDOT Region 1:

- NYSDOT plays a key role in work zone coordination for the projects with regional traffic impact.
- NYDSOT has utilized the Transportation Management Center (TMC) for disseminating work zone information to meet the needs of real-time traffic information for road users. TMC information is available on multiple fronts, including 511.

- NYSDOT Region 1 does not hold a unified database in-house but a list of current construction projects and upcoming projects in 5 years is provided annually.
- There is a need to have a new tool in the near future that is able to conduct queueing, travel delays and proper user cost analysis.

NYSDOT Region 11 (New York)

Region 11, the New York City Region, serves approximately 7.5 million people and has approximately 235 miles of the most heavily used freeways and expressways as part of the New York State Arterial System (45). The Region's challenge is to provide the public with a safe, durable transportation system and to do so while improving the quality of developed and natural communities (45). Same as Region 1, Region 11 plays an important role in work zone coordination for the projects with regional traffic impact.

On March 1st, 2017, the research team presented its findings based on previous interviews with other stakeholders in the greater NYC metropolitan area to Region 11. One of the main focus areas of the Team's presentation was the details of the functionalities of an ideal work zone tool that will be suitable for Region 11. This proposed work zone management tool is a computerized application that will use a unified online work zone database that can be queried and used for work zone coordination efforts via a map-based web interface, which can be accessed on-line only by authorized users. More details about the ideal coordination tool can be found in the following need assessment section.

Based on the March 1st, 2017 interview conducted and follow-up comments received on April 6th, 2017, the needs and recommendations from Region 11 construction, operations and planning groups are summarized as below.

- For NYSDOT Region 11 input data and information of the proposed work zone tool need to be clearly identified.
- A protocol / procedure needs to be developed to enhance the workflow for NYSDOT Region 11 project once a work zone conflict is found (i.e. schedule a working meeting with NYSDOT Region 11 stakeholders, identify possible ways to address the conflict, etc.). Agency or personnel who will be responsible for data input and maintaining the tool needs to be identified and a most up-to-date contact list must be kept.
- NYSDOT Region 11 suggested to consider three different time frames for work zones: long-term planning, short-term planning, and real-time operations.
- NYSDOT Region 11 suggested to start with the regional highway system and then include parkways as a separate layer due to its complexity.
- NYSDOT Region 11 suggested the consideration of different time periods for lane closures caused by construction. For example, some projects may require closure of different numbers of lanes during daytime and nighttime.

- The proposed NYSDOT Region 11 work zone tool should provide different levels of permission to access certain data and functionalities.

New York Metropolitan Transportation Council (NYMTC)

NYMTC is the designated Metropolitan Planning Organization (MPO) for New York City, Long Island, and the lower Hudson Valley. NYMTC council members are elected officials and heads of transportation and environmental agencies responsible for developing a shared vision and goals for the region, and adopting the Transportation Improvement Program (TIP), Transportation Conformity Determination, Unified Planning Work Program (UPWP), Regional Transportation Plan (Plan) and Congestion Management Process Status Report that are specified in federal regulations (46).

NYMTC's voting members include New York State Department of Transportation, New York City Department of Transportation, New York City Department of City Planning, Metropolitan Transportation Authority, Putnam County Executive, Nassau County Executive, Rockland County Executive, Suffolk County Executive, and Westchester County Executive. In addition, NYMTC also has 7 advisory council members that are Port Authority of New York & New Jersey, New Jersey Transit, North Jersey Transportation Planning Authority, New York State Department of Environmental Conservation, Federal Transit Administration - Region 2, Federal Highway Administration NYS Division, and U.S. Environmental Protection Agency.

Generally, NYMTC is responsible for coordinating planning and funding for studies and transportation improvements, it does not directly coordinate, schedule, or manage work zone projects. Its member agencies have the responsibility of day-to-day transportation issues such as design and repair of roads or maintenance and operations of facilities. There is coordination among NYMTC members for work zone project management.

NYMTC is obligated to manage Transportation Improvement Program in the planning area. Construction or work zone information may be included in the TIP projects but is not directly managed by NYMTC. The TIP program defines all of the federally-funded transportation projects proposed for planning, design and implementation in the region over a five-year period (46).

The interview also indicated that there is no mandated law for MPO in terms of work zone planning or operation. However, NYMTC has a department for congestion forecasting as a part of its congestion management program (CMP) that generates CMP report every four years. The CMP report usually lists predicted congested locations and extent of congestion.

For data and modeling efforts, NYMTC uses an activity-based travel demand model called New York Best Practice Model (NYBPM) for regional planning.

NYBPM is used as a platform to make sure the same standards of traffic demand are used by various member agencies. Meanwhile, other models can be used for sophisticated work.

Although NYMTC does not have a department for handling complaints regarding roadway disruptions due to work zones, it has an annual public review meeting receiving feedback from general public regarding various projects. During the meeting, complaints/concerns are sent to the specific member of the NYMTC consortium. For instance, complaints related to Long Island Rail Road (LIRR) would be sent to MTA.

The impact of Vision Zero is direct for individual member agencies. Secondary impacts of Vision Zero such as reduced speed limits are incorporated into NYMTC's planning process.

For special events, the coordination is usually conducted through state participation. NYMTC does not have procedures at MPO level, but member agencies have.

Key Points from the NYMTC Interview

The research team identified the key points listed below based on the interview with the NYCT:

- NYMTC is not directly involved in the operation of work zones. Its member agencies are responsible for work zone project management. Coordination happens among NYMTC member agencies, but not at the MPO level.
- NYMTC's TIP projects may have construction or work zone related information but work zones are not directly managed by NYMTC.
- NYMTC does not have any tool for work zone management or planning.
- NYMTC does not involve in the process to issue permits for constructions.
- NYMTC does not have a department for handling complaints specifically regarding roadway disruptions due to work zones, but it has an annual public review meeting receiving feedback from general public.
- Secondary impacts of Vision Zero such as reduced speed limits are incorporated into NYMTC's planning process and its regional planning model NYBPM.
- Special event coordination for work zones is conducted through state participation and member agencies. NYMTC does not have official procedure at MPO level.

The following section presents the needs assessment for NYCDOT based on the lessons learnt from the conducted interviews and the in-depth review of CIA and WISE tools, and also lists the requirements for an ideal work zone coordination tool.

NEEDS ASSESSMENT

NYCDOT / NYSDOT's goal is to develop enhanced strategies for coordinating and planning work zone projects of different scales, quantify the impact of various combinations of proposed work zones within a corridor or in a specific region, and reduce the negative impacts of work zones (based on NYCDOT interview on October 30th, 2015). The key objective of this project, as stated in the 2013 CIDNY Request for Proposal (RFP), is 1) to review the related literature and state of practice in the US 2) to capture the current of state-of-practice in the NY City Metropolitan area through extensive interviews with area agencies 3) to assess capabilities of existing tools with a sharp focus on the tools identified in the RFP namely, Construction Impact Analysis (CIA) and Work Zone Impact and Strategy Estimator (WISE) tools, and determine the feasibility of their customization with respect to NYCDOT's needs and requirements, cost of adoption and modification, among other issues. The detailed review of CIA and WISE tools is presented in the In-Depth Review of CIA and WISE section of this report. This section is devoted to outlining the NYCDOT's needs and requirements by incorporating the lessons learnt from the interviews with various transportation agencies in the NYC metropolitan area and the findings from the review of the literature and most relevant software tools.

Requirements for Efficient Work Zone Coordination

As stated in a recent FHWA report (47) a successful coordination / consolidation effort must have the following features:

(a) Identify the involved parties and the time when the effort should begin,

(b) Estimate the effects of work zones,

(c) Provide visibility and accessibility to project information.

Addressing the first item on the above list requires a collaborative effort on the transportation agencies' part. Addressing the latter two items is more demanding. Regarding the estimation of the impact of work zones, there are several software tools specifically developed for this purpose such as WISE (25), QuickZone (48), RILCA (49), Oregon DOT's WZTA tool (50) and DDOT's WZPMS tool (51); however, most of the available tools, or any tool that will be developed for this

specific purpose requires extensive and up-to-date roadway infrastructure and hourly traffic volume data, which are not always readily available.

With regards to the last item on the above list, ensuring better visibility of and accessibility to project information requires a unified database of all project information preferably coupled with a project location visualization tool that must assist the lead agency in identifying coordination needs and determining suitable coordination actions.

For an effective work zone coordination effort, the above listed items must be addressed simultaneously. In other words, the traffic impact analysis tool and the unified work zone database should be integrated seamlessly to ensure an effective and robust coordination effort. Also, the combined computer tool must be designed to cater to the needs and capabilities of all the parties involved in the coordination effort. In addition, having a unified database with the latest and reliable work zone information requires an effective and timely data feed from multitude of divisions within an agency (or agencies), which can only be accomplished by the close collaboration of all the involved parties.

Requirements for NYCDOT

As identified in the interviews conducted with the transportation agencies in the NYC metropolitan area, conflict analysis for work zones is only conducted for long-term projects, and a higher priority is given to capital projects that are at the regional level over short-term projects such as maintenance and utility work. As it is beneficial for various agencies to collaborate with each other and coordinate long term and significant projects, it would be beneficial for NYCDOT to effectively “coordinate”, “plan”, operate, and quantify the impact of these more frequent short term projects with respect to each other as well as with long-term more substantial projects.

In fact, FHWA requires transportation agencies to consider the planning and coordinating of maintenance and operations (M&O) activities (3). However, as stated in the State of Practice section of this report, there is not a commonly accepted DOT policy that addresses how agencies should coordinate or consolidate projects. In addition, only a few states utilize computer tools, specific to regional or corridor based work zone coordination of significant and long-term projects only. Similarly, as evidenced in our interviews, within NYCDOT there is not an organizational chart of NYCDOT divisions geared towards work zone coordination such as identification of responsible divisions, management and dissemination of information, and relationship and hierarchy between the involved divisions.

Within NYCDOT / NYSDOT, the team believes that the key issue that needs to be addressed is the lack of a unified and easily accessible database of the ongoing and scheduled work zones that is updated on a regular basis according to a

predefined schedule. As a result, currently the dissemination of the schedules of these work zones might not be as effective as they should be in terms of helping project managers to cooperate using the updated information in order to make near optimal decisions about timeline of planned work zones.

The following subsections describe the specific needs of the NYCDOT / NYSDOT towards adopting or developing a computerized tool for coordinating and planning work zones to minimize their impacts on traffic in particular and on commuters in general.

Need to Identify Involved Parties

Highlight: There is a need to create an on-line and easy to access version of the official organizational chart that describes the roles and responsibilities of each division within NYCDOT for work zone coordination. As per the comments of OCMC, this information already exists thus making it easily accessible and modifiable to reflect changes over time can be useful for improved communication within the agency. Eventually this on-line and easily organizational chart might contain responsibility / contact information about other agencies in the study region. This can improve communication and information sharing.

Over time, additional improvements can be achieved by defining or if needed, re-defining roles and responsibilities within the agency for different types of projects, and perhaps forming a task force or a designated team responsible only for work zone coordination and conflict mitigation. Nevertheless, this step is not always straightforward because of the complexity of the operational work flow within the department. For example, NYCDOT has various divisions within the department that are responsible for short or long term construction projects. In addition, due to the city's importance in the tri-state area, NYCDOT is in constant coordination and collaboration with other agencies in the city and in neighboring states. It will be beneficial to improve these collaboration and coordination efforts using emerging technologies and continued communication.

The exchange of information and documentation and discussions on planned work zones is maintained by agencies, relying in meetings to discuss schedules and impacts.

Creating a living organizational chart indicating the decisions and stakeholders involved, including roles and responsibilities, as being practiced by the WSDOT, can significantly improve the coordination process for work zones.

Need for a Unified and Comprehensive Unified Database

Highlight: There is a need to create and maintain a common, preferably online comprehensive unified database across the NYCDOT that includes network and

traffic information in addition to the work zone information that is currently being managed by OCMC

Currently OCMC division manages an online database of the current and planned utility work in the city, and Roadway Repair and Sidewalk Repair and Management divisions provides the planned work zones on the NYCDOT website and in NYCSTREETS. Each division has its own database and they utilize different tools to store project information. Ideally, a unified database should be utilized, in which all planned and active projects, whether long-term or short-term, are stored and shared amongst various divisions within the NYDOT. As mentioned in the interview section, the database should be able to automatically extract the details of work zones such as the time and date of work zone, number of lanes closed, project type, work zone description, responsible division, contact person, etc[17]. This proposed database would increase the visibility of all types of projects conducted by the agency, and lead to a collaborative environment among all involved parties. Examples for such database include the GLRTOC and WSDOT's CIA tool database.

Need to Explore Technology Driven Solutions to Improve Effectiveness of Current Coordination Practice

Highlight: There is a need to explore technology driven solutions to improve the effectiveness of on-going collaborative actions within the divisions of the NYCDOT / NYSDOT.

NYCDOT / NYSDOT, in which an internal meeting including all parties that are involved in projects that require work zones, such as OCMC, Roadway Repair Division, DDC, Bridges Division, Sidewalk Repair and Management Division, is held regularly. TRANSCOM, in partnership with NJDOT, holds monthly meetings with people involved are conducted to discuss key points in coordinating and mitigating impacts of work zones. As suggested by FHWA (FHWA, Work Zone Best Practices Guidebook., 2016), "TRANSCOM's methods can easily be scaled down to help coordinate projects across various regions or districts within a State, through similar types of construction coordination meetings or the collection of upcoming project information in a statewide project database."

This, in addition to holding physical meeting with outside parties including the Mayor's office and TRANSCOM, emerging technological solutions such as a web-based information sharing and discussion tool can be designed and deployed. This kind of technological add-on can improve response and decision times. For example, special events, such as marathons, festivals, games, and other events

[17] As per the comments of OCMC on March 24th, 2017, this is a planned update in NYCSTREETS.

that happen in a short timeline can be coordinated with construction events without having to conduct in person meetings. The main point is to explore technology solutions that can enhance on-going coordination activities lead by OCMC. Especially considering the involvement of different agencies and transportation systems in coordinating special events including OCMC, PANYNJ (operates PATH), NYCT (provides extra bus lines in events), NYCDOT (transit operations and planning), and the Mayor's Office (who issues the permits for Special Events), it is important to explore new technologies that can reduce complexities and provide improvements.

Need to Estimate the Impact of Work Zones

Highlight: There is a need to systematically estimate the impact of work zones before implementation. Currently, only long-term and significant projects require traffic modeling for impact analysis. However, roadway repair and utility projects, which are short term and do not require traffic analysis, are much greater in number and can cause significant traffic disruptions and safety problems.

NYCDOT already conducts traffic impact analysis for long-term and significant projects as mandated by the FHWA (52). Similar analysis should be performed for short-term projects as well. However, it is not realistic to perform detailed traffic impact analysis for all work zones. Therefore an alternative method can be adopted to provide a quick and reliable estimative of traffic impact for work zones.

As mentioned before, addressing this specific need requires extensive and up-to-date roadway infrastructure and hourly traffic volume data, which are not always available.

Requirements for an Ideal Coordination Tool

Based on the assessment of the needs identified in this section, it can be claimed that the identified parties within the NYCDOT and their counterparts outside the agency must collaborate and adopt a computerized tool that uses a unified database to coordinate of work zones. That is why the CIDNY Task 2 RFP also clearly requested the review of WISE and CIA tools. This section lays out the desired properties of such a computerized tool.

The main goal of this section is to clearly describe the functionalities of an "**ideal work zone management and coordination too**l (work zone tool)" based on the outcomes of the previous tasks. It is clear that all of these functionalities might not be attainable in the near future or there might not even be a need to develop a brand new tool. In fact some of these functionalities can be incorporated into existing tools such as NYCSTREETS that is currently being maintained by OCMC. However, the research team believes that it is important to describe an "ideal work zone tool" for the sake of presenting the full picture based on the findings in

previous tasks. To re-iterate our main goal one more time, what is presented here is a fully integrated ideal computer tool that incorporates all the functionalities that are deemed important for effective work zone management and coordination in a complex urban network.

Figure 29 illustrates the framework of an ideal computerized tool for coordinating work zones. As seen in the figure, the current and planned work zones initiated by various divisions within the agency are fed into an extended work zone database. This extended database should be hosted at a server within the agency and automatically extracted to an online database via periodic XML feeds. The information within this online database can then be reached, queried and used for coordination efforts via a Map-Based Interface, which can be accessed online via authorized users. A similar application was developed successfully for NJDOT by the authors and presented in Ozbay *et al.* (53).

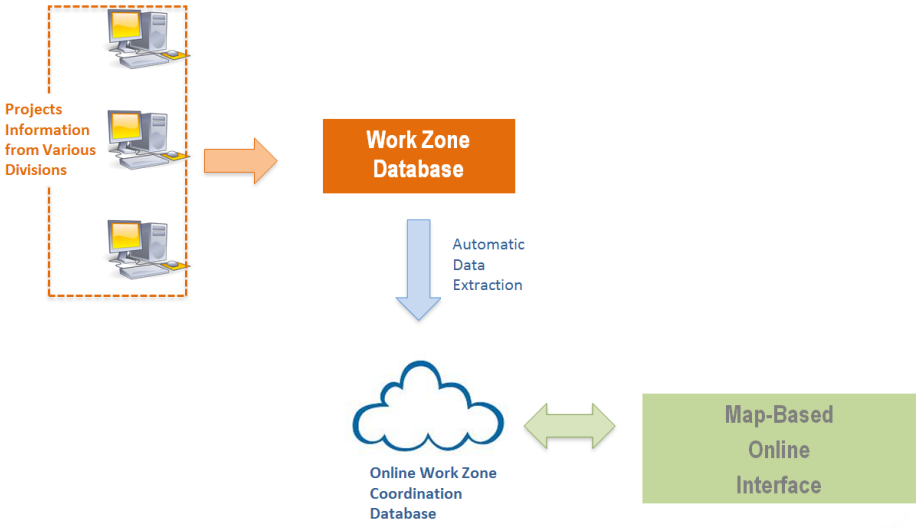


Figure 29: Framework for an Ideal Work Zone Coordination Software Tool[18]

The following subsections briefly outline the desired functional properties of an ideal work zone coordination software tool.

Maintain a Work Zone Projects Database

The tool should be able to store and display detailed information on all current and planned work zones. Information should include the project number and description, roadway details, work type (such as maintenance, utility, repairs,

[18] As per the feedback from the NYCDOT / OCMC, "some of these requirements discussed in this section and depicted in Figure 29 can be addressed by integrating NYCSTREETS and "Pavement Works" DOT databases.

resurfacing), number of lanes closed, scheduled time and date, the division and project manager information. The database must also contain the estimated level of impact expected for the work zone, which should be automatically estimated by the tool.

The tool should also identify potential conflicts automatically and provide a simple approach for scheduling new work zones based on existing long-term projects and short/mid-term work zones expected to happen in the area. The information in this database has to be constantly updated to reflect the change in work zones and construction phases to avoid inaccuracies that lead to erroneous decision making.

To better facilitate regional coordination, the database should be designed in a way that it can easily be integrated to TRANSCOM'S OpenReach database.

Estimate the Impact of Proposed Work Zones

It is important to provide a quick estimative of the delay that would be created by proposed work zones. This analysis must provide simple queue estimation, speed reduction propagation and delay created by a possible roadway capacity reduction. It should be emphasized that this requirement for an ideal tool is not meant to replace detailed traffic modeling and analysis done for major work zone projects. These have to be done independent of this requirement since there is no feasible way of developing a functionality that can conduct such detailed traffic modeling and analysis of major projects as part of this ideal tool. What is proposed here is a quick but robust impact estimation approach that requires minimum amount of data and time to be operationalized. For example, a simple deterministic queueing approach that only required minimum data as input van be adopted. The deterministic queueing approach can be enhanced by introducing a probabilistic version that captures uncertainties inherent in demand and supply values.

It should be noted that the successful implementation of this functionality depends greatly on the available hourly link volumes and capacities as well as roadway infrastructure data for the whole network. As mentioned earlier, extensive and up-to-date roadway infrastructure and hourly traffic volume data are not always available. However, much of this data, especially speed and travel time data, can be obtained from existing databases and / or third party providers or estimated using available traffic sensor count database, as shown in Ozbay *et al.* (53).

The required parameters for work zone impact analysis include the start and end time of the work zone, number of lanes closed, capacity under normal and work zone conditions, passenger car equivalency, average gap between vehicles, average vehicle length, truck percentage and lane width. These parameters are used to estimate the deterministic vehicle delays and queue lengths. It is important to recognize that it is significantly more difficult to acquire the above information for local streets compared with main highways. This, the initial focus should be on main roadways in the City.

In addition to mobility impacts, the safety impacts of proposed work zones can be estimated using the existing or newly estimated crash reduction factors, as described by FHWA (54).

Conduct Conflict Analysis

The tool should be able to automatically identify conflicts between different upcoming projects occurring in the same area that may adversely affect traffic. As per the remarks of OCMC, this is currently done by OCMC but the tool can help current efforts by automating certain aspects of this effort and also adding new queries / functionalities that can introduce improvements.

Conflict analysis can be conducted by using two main parameters: (a) Overlap period and (b) Radius. In searching conflicting projects, the tool should find out if two projects are closer to each other than the radius distance and overlap by more than the specified number of days.

It should be noted that the tool should have a multi-dimensional query functionality to identify the presence of other work zones in the vicinity of another work zone; however, the final decision must be based on the users' expertise and they should determine if one of the listed work zones in fact is an actual conflict. This query functionality will automate the current practice done by OCMC when issuing permits and enable the user to explore various scenarios by using different types of spatio-temporal conflict scenarios.

Another important feature is to automatically identify the information of the responsible division and contact person for the projects that are in conflict with each other and once the validity of the conflict is confirmed by the user, a warning in the form of an email can be automatically sent to the involved parties to facilitate a coordination effort that is currently being done by OCMC. The main idea here is to provide automated functionalities that will help OCMC to improve their current practice. Clearly, there is a need to further consider what kind of automation is needed in close coordination with OCMC and other involved parties if and when such a tool is planned.

Identifies Hot Spots

Visually identifying hot spots on a map can help managers to postpone some of the projects, or even to consider create enforcement strategies to provide safety conditions for the road users in these areas. The use of the "unified database" that includes data from all agencies (including NYC Dept. of Buildings), utilities and smaller private work sites (active and planned) will be an enhanced feature when identifying hot spots. Also, the tool should be able to create and display visually attractive maps that contain information from the State's and City's GIS systems and reports on these areas to be available for the public and community, in order for stakeholders to plan their activities according to the scheduled projects.

Conducts Benefit Cost Analysis of Work Zone Coordination

The cost of work zone coordination is the penalty of delaying one work zone or integrating it in another work zone. The numbers used to quantify penalty are not only readily available but also are different from work zone to work zone. Cost estimates can be obtained from the project managers, since they will have the most accurate numbers.

On the other hand, the benefit of coordinating work zones should be estimated by the tool based in terms of the reduced vehicular delays. Input requirements should be minimum and intuitive and the analyst should not be required to enter information that requires any economic background. Based on the comments of OCMC, C/B analysis is done when necessary. It is however useful to incorporate C/B in a tool to automate this process and make it easier to conduct C/B analysis by making it an integral part of the ideal tool described in this section. Although WISE has a simple C/B analysis function, CIA does not have one in its current version. Thus, it is important to have a tool that can help conduct C/B analysis as an integrated function without needing to use another tool that will require extensive data preparation.

The following are the two likely scenarios of work zone coordination and the resulting benefits that can be quantified using the described C/B analysis functionality.

Scenario 1: Conflicting Work Zones on the Same Roadway

Figure 30 shows two work zones adjacent to each other. It the conflicting projects are less than a mile apart and they are both in conceptual design phase, then it is assumed that there is a possibility of consolidating these two projects into a single one. The benefit of a possible consolidation scenario is removing one work zone and therefore the delays it imposes on traffic. The tool should estimate the delays that each work zone imposes on traffic and converts them into monetary values using a unit value of time (VOT).

The benefit of consolidating work zones is the value of total delay of the work zone that is removed, assuming that the length of the consolidated work zone is no longer than the maximum of the two separate work zones. Occasionally, it is not possible to consolidate two projects for various reasons. In that case, the tool should allow users to determine the benefit of re-scheduling one of the work zones to another time period.

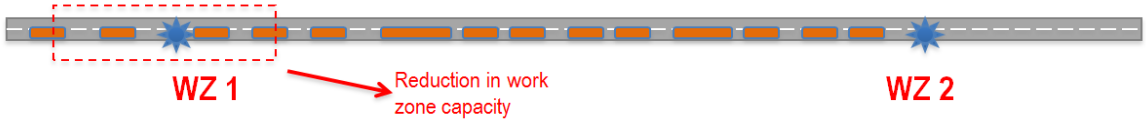


Figure 30: Two Work Zones on the Same Roadway

During this process, the benefit cost analysis depends on the expertise of users during this process. If one of the work zones is easier to re-schedule, the computerized tool should estimate the reduction in cost of delay by re-scheduling one of the projects during another time period.

Scenario2: Conflicting Work Zones on Different Roadways

Based on the proximity work zones (Figure 31), users can decide whether one of the work zones should be re-scheduled.

Figure 31: Proximity of Two Work Zones

The tool should allow users to estimate the delays when the selected project is rescheduled and when it is status-quo. The benefit of rescheduling is the reduction in total delay costs. The tool should also provide an estimated percentage of traffic diversion between roadways, and estimate benefits accordingly.

Running a traffic assignment algorithm is another method of traffic diversion when work zone exists on a roadway. However, traffic assignment requires a network-wide origin-destination matrix along with other specific input as calibrated link travel times. Thus, this process of performing traffic assignment to estimate diversion volumes for a specific work zone coordination scenario will be extremely time consuming and costly. As mentioned in this report, the WISE software developed by FHWA follows this approach (25). It can either import an existing travel demand model or let users create a new network. This tool is tested by the research team and the results are presented earlier in this report. It is observed that its interface is built in open-source software which is not scalable and not user-friendly. Its GUI may encounter unexpected compatibility issues and report vague error messages. In addition, it was found out that sufficient prior knowledge of the traffic demand model is required as manual modifications are always needed when importing an existing network, travel demand or creating a new network from scratch. Therefore, the proposed benefit cost analysis approach is a more practical method that incorporates the expertise and rationality of the users.

Include Up-To-Date Roadway and Traffic Data

As mentioned earlier, the crucial functionalities of an ideal work zone management tool, namely, estimating work zone impact and benefit of coordination, depends greatly on the availability of up-to-date roadway infrastructure and hourly link traffic volume data. Based on the input from OCMC, they request this information when needed. In the long-run, this information can be made available in real-time as an add-on functionality to the existing NYCSTREETS that is the main work zone tool in NYC.

In a real-time version, volume and speed data can be obtained via the available roadway sensors or historical counts. However, it is not possible to have counts for all the links in the network. There are however effective methods for estimating hourly roadway volumes using the AADT information and available sensor count data, as shown in Ozbay *et al.* (53). A similar approach can be adopted by the NYCDOT.

CONCLUSIONS AND RECOMMENDATIONS

The previous section identified needs of the NYCDOT / NYSDOT (Region 11) towards adopting or developing a computerized tool for coordinating and planning work zones to minimize their impacts on traffic. It also outlined the requirements for an ideal computerized tool that would best fit the listed needs of the department.

As mentioned previously in our review, CIA is used by WSDOT effectively to coordinate and manage the 'Hot Spots' of the state highways through a web-based interface. CIA is a very simple but efficient tool to keep track of construction projects and coordinate intra-agency the efforts to combine work zones. Its results are used mostly for information management and internal coordination, sometimes with users and stakeholders' engagement, and it could be expanded for traffic analysis and congestion mitigation.

WISE, on the other hand, is a useful software for coordinating and organizing work zone schedules, but with certain limitations. Its functionalities such as in-software traffic impact and cost analysis, and project sequencing are among the major highlights of this tool. It is capable of assessing optimal sequencing, evaluating cost-effectiveness of strategies to reduce or manage road user cost. However, the interface is built using an open-source software which is not scalable and not user-friendly. Its GUI may encounter unexpected compatibility issues and report unclear error messages. It was found that sufficient prior knowledge of traffic demand models is required due to the need for extensive manual modifications needed when importing and /or crating the initial analysis network. Table 8 lists the functionalities of WISE and CIA tools against the requirements for an ideal

computerized coordination tool, as identified in the previous section. Below are the description of if and how the tools can be modified to match the listed requirements.

Table 8: Evaluation of WISE and CIA Tools' Functionalities

Requirements for an Ideal Computerized Coordination Tool	**WISE**	**CIA**
Maintain a Work Zone Projects Database	No	Yes
Estimate the Impact of Proposed Work Zones	Yes	No
Identify Hot Spots	No	Yes
Conduct Benefit Cost Analysis of Work Zone Coordination	Yes	No
Include Up-To-Date Roadway and Traffic Data	No	No

Maintain a Unified Work Zone Projects Database: WISE is a strategic planning tool with some operational capabilities; however, it does not utilize and maintain a work zone project database. In its Planning Module, WISE allows users to edit all the information of the projects that are being evaluated and to create a sequence of the projects in the horizon. In other words, the tool helps its users to coordinate only the projects that are fed into its planning module. On the other hand, CIA utilizes a zone project database that is being kept up-to-date by the WSDOT. However, both tools are being used to coordinate and schedule only long-term and significant projects. Currently, the database that the CIA tool is based on includes only this type of projects. As mentioned before in the Needs Assessment section, it would be beneficial for NYCDOT / NYSDOT to effectively coordinate, plan and quantify the impact of the relatively short term yet frequent projects with each other and also with long-term projects. Based on NYSDOT Region 11 interviews, it is important to categorize work zones based on the way they are conceptualized namely, long-term and short-term planning, and real-time operations. It is feasible to start with the regional highway system and then include local street network in phases as a separate layer due to its complexity.

Remark: WISE is designed to assess the impact of long-term and significant work zone projects only. CIA tool, however, is suitable to be used for coordinating short-term work zones as long as its database is redesigned to include this type of work zones.

Estimate the Impact of Proposed Work Zones: CIA tool does not estimate the impact of work zones. WISE, on the other hand, via its Operation Module allows the users to estimate the evolution of system-wide traffic flow dynamics patterns resulted from individual drivers seeking the best routes to their destinations responding to changing network demand, supply, or control conditions (32).

Remark: CIA tool lacks this important functionality. Although WISE can consider the impact of work zone(s) in a network-wide scale, this process takes a considerable amount of time. While this process time is acceptable for coordinating long term projects, it can be a drawback for the day-to-day use of the tool.

Identify Hot Spots: This functionality is a by-product of utilizing a current database of work zone projects. Since WISE tool does not utilize such a database, it does not have this functionality. It is assumed that hot spots are already identified and the candidate projects are selected before the WISE tool is utilized. On the other hand, CIA does have the functionality of identifying areas in the network where considerably large number of projects are happening at the same period.

Conduct Benefit Cost Analysis of Work Zone Coordination: The ability of a tool to estimate the benefits and costs of work zone including coordination of multiple work zones depends on its ability to estimate and quantify the impact of individual or combined work zones. Since CIA tool does not have the functionality of estimating and quantifying the impact of work zones, it does not embody this specific requirement. WISE tool, however, has the ability to test best/cost for agency cost related to demand reduce strategies and construction duration based strategies in its planning module and user costs estimated by DynusT in its operational module.

Remark: CIA tool cannot be modified to include this functionality unless it is updated to include a functionality that can estimate the impact of work zones on traffic.

Include Up-To-Date Roadway and Traffic Data: The most noticeable functionality that both tools currently lack is the ability of incorporating up-to-date roadway and traffic data. As mentioned in the previous section, estimating work zone impacts and the benefits of work zone coordination depends greatly on the availability of up-to-date roadway infrastructure and hourly link traffic volume data. WISE circumvents this functionality by using the roadway information and the link volumes estimated by the available traffic demand models. In addition, actual link traffic volume data can also be imported into the software in a pre-defined spreadsheet format.

Remark: Modification of these tools to include up-to-date roadway and traffic data which is not a straightforward task given the current structure of CIA and WISE tools.

In conclusion, based on our review of these software tools, none of the tools are complete at its fullest to address all the needs for coordinating work zones when multiple stakeholders and agencies are involved. Instead, a hybrid approach combining the best elements of each software tool seems to be the best approach for building a complete tool for coordinating schedules and traffic analysis.

References

1. FHWA. *RealCost User Manual.* 2004.
2. NHTSA. Fatality Analysis Reporting System. [Online] 2014. [Cited: 06 13, 2016.] http://www-fars.nhtsa.dot.gov/Main/index.aspx.
3. FHWA - Federal Highway Administration. *Work Zone Safety and Mobility Rule.* s.l. : Department of Transportation, 2004.
4. Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide).* s.l. : Project Management Institute, 2013.
5. NCHRP. *Highway Construction Coordination to Minimize Traffic Impacts.* s.l. : National Cooperative Highway Research Program, 2006.
6. Parveen Sukumaran, TaeHoon Hong, Mehmet Emre Bayraktar, Makarand Hastak. Validation of a Model for Predicting Schedule Changes in Highway Work Zones—Case Studies. *Journal of Transportation Engineering.* August 2006, pp. 638-648.
7. Lee, Hsin-Yun. Optimizing schedule for improving the traffic network of work zone on roads. *Automation of Construction.* May 13, 2009, pp. 1034-1044.
8. Mehmet Emre Bayraktar, Makarand Hastak. A decision support system for selecting the optimal contracting strategy in highwaay work zone projects. *Automation in Construction.* March 13, 2009, pp. 834-843.
9. *Scheduling of Lane Closure using Genetic Algorithms with Traffic Assignments and Distribuited Simulations.* Wenteng Ma, Ruey Long Cheu, M. ASCE, Der-Horng Lee. 2004, Journal of Transportation Engineering, pp. 322-329.
10. *A Proposed Model for Predicting Motorist Delays at Two-Lane Highway Work Zones.* Han, M. J. Cassidy and L. D. no.1, 1993, Journal of Transportation Engineering, Vol. 119, pp. 27-42.
11. Jiang, Y. *Traffic Characteristics and Estimation of Traffic Delays and User Costs at Indiana Freeway Work Zones.* s.l. : Indiana Department of Transportation, 1999.
12. *Optimal Work Zone Lengths for Four-lane Highways.* Schonfeld, S. Chien and P. no.2, s.l. : Journal of Transportation Engineering, 2001, Journal of Transportation Engineering, Vol. 127, pp. 124-131.
13. *Analysis of life-cycle maintenance strategies for concrete bridge decks.* Huang, Y., Adams, T. M. and Pincheira, J. A. 9(3), 2004, Journal of Bridge Engineering, pp. 250-258.
14. *Methodology for Computing Delay and User Costs in Work Zones.* M. V. Chitturi, R. F. Benekohal and A. Z. Kaja-Mohideen. 2008, Journal of the Transportation Research Board, Vol. 2055, pp. 31-38.
15. *Work Zones as a Series of Bottlenecks.* Benekohal, H. Ramezani and R. F. 2012, Journal of Transportation Engineering, Vol. vol. 2272, pp. pg. 67-77.
16. *Methodology to Analyze Queue Length and Delay in Work Zones.* H. Ramezani, R. F. Benekohal and K. A. Avrenli. 2010. Presentation at the 90th TRB Annual Meeting.

17. *Theoretical Approach to Predicting Traffic Queues at Short-Term Work Zones on High-Volume Roadways in Urban Areas.* Ullman, G. L., Dudek, C. L. D.C., 2012 , 2012, Transportation Research Record: Journal of the Transportation Research Board, Vol. 1824, pp. pp. 29-36.
18. *Traffic Flow in the Morning Commute.* Newell, G. F. 1, 1998, Transportation Science, Vol. 22, pp. 47-58.
19. *On Kinematic Waves: A Theory of Traffic Flow on Long Crowded Roads.* Whitham, M. J. LightHill and G. B. A, 1995, Proc. of Royal Society, Vol. 229, pp. 317-345.
20. NCHRP. *Design of Construction Work Zones on High-Speed Highways.* Washington DC : Transportation Research Board, 2007.
21. ODOT. *FHWA Work Zone Rule Virtual Workshop - Oregon's Work Zone Traffic Analysis Program.* Salem : s.n., 2008.
22. Coleman, Tony. FHWA Work Zone Project Coordination Webinar, Oregon Department of Transportation. [Online] 9 2012. [Cited: 6 29, 2016.] http://www.ops.fhwa.dot.gov/wz/construction/webinar92412/odot/.
23. Coalition, Great Lakes Regional Transportation Operations. *Smart Work Zones – GLRTOC Corridor Practices.* s.l. : EJM Engineering Inc, 2015.
24. Caltrans. Planned Lane Closures. [Online] 2007. [Cited: 6 29, 2016.] http://lcswebreports.dot.ca.gov/lcswebreports/.
25. FHWA. WISE: Work Zone Impacts and Strategies Estimator Software (R11). [Online] 2014. [Cited: 06 28, 2016.] http://www.fhwa.dot.gov/goshrp2/Solutions/All/R11/WISE_Work_Zone_Impacts_and_Strategies_Estimator_Software.
26. SHRP2. *Work Zone Impact and Strategy Estimator (WISE) Software Validation and Pilot Tests.* 2014.
27. Corbin, John, et al. *Smarter Work Zones Webinar Series: Work Zone Impacts and Strategies Estimator (WISE) Software Pilot Sites.* s.l. : FHWA.
28. Goss, Lise. [Online] WSDOT, 11 2009. [Cited: 7 15, 2016.] ftp://ftp.gis.cwu.edu/nancyh/rem515-Nov12.
29. Accela. Envista. [Online] Accela, 03 31, 2016. [Cited: 6 03, 2016.] http://www.envista.com/baltimore-and-bge-adopt-envista.
30. FHWA. Work Zone Best Practices Guidebook. [Online] 2016. [Cited: 06 03, 2016.] http://ops.fhwa.dot.gov/wz/practices/practices.htm.
31. NYCDOT. NYCStreets Permit Management System. [Online] [Cited: 10 20, 2016.] https://nycstreets.net/.
32. DynusT. [Online] DynusT Lab. [Cited: 6 29, 2016.] http://dynust.net/.
33. DynuStudio. [Online] RST International INC. [Cited: 6 29, 2016.] http://www.rstintl.net/newsite/index.php/product/dynustudio.
34. *Multi-Resolution Model Integration Technical Memorandum.* s.l. : Center for International Intelligent Transportation Research, 2010.
35. DOT, NYC. Street Works Manual. [Online] March 11, 2016. http://streetworksmanual.nyc/.
36. —. Street and Roadway Construction. [Online] March 11, 2016. http://www.nyc.gov/html/dot/html/infrastructure/construction.shtml.

37. NYCDOT. NYCStreets Permit Management System. [Online] [Cited: March 11, 2016.] https://nycstreets.net/public/permit/search.
38. TRANSCOM. TRANSCOM. [Online] March 11, 2016. http://www.xcm.org/XCMWebSite/Index.aspx.
39. Systems, Coval. What is OpenReach? [Online] [Cited: March 4, 2016.] http://www.covalsystems.com/latest/openreach/automation.html.
40. PANYNJ. Overview of Facilities and Services. [Online] [Cited: 10 20, 2016.] http://www.panynj.gov/about/facilities-services.html.
41. —. Capital Plan Summary: 2014-2023. [Online] [Cited: March 11, 2016.] https://www.panynj.gov/corporate-information/pdf/2014-public-capital-plan.pdf.
42. MTA. MTA Info. [Online] MTA, 04 12, 2016. [Cited: 04 12, 2016.] http://web.mta.info/mta/network.htm.
43. NYCDDC. New York City Department of Design and Construction. [Online] [Cited: 7 6, 2016.] http://www1.nyc.gov/site/ddc/index.page.
44. Construction, New York City Department of Design and. *Design Consultant Guide.* 2015.
45. NYDSOT. New York State Department of Transportation. [Online] [Cited: 9 21, 2016.] https://www.dot.ny.gov.
46. NYMTC. New York Metropolitan Transportation Council. [Online] [Cited: 10 9, 2016.] https://www.nymtc.org/.
47. FHWA. *Guide to Project Coordination for Minimizing Work Zone Mobility Impacts, FHWA-HOP-16-013.* 2016.
48. *QuickZone A Work Zone Delay Estimation and Analysis Tool.* Hardy, M. H., Larkin, J. J., and Wunderlich, K. E. 2002. ITS America Annual Meeting.
49. *Interactive Lane Closure and Traffic Information Tool Based on a Geographic Information System.* Bartin, B., Ozbay, K. and Mudigonda, S. 44–55, 2012, Transportation Research Record: Journal of the Transportation Research Board, Vol. 2272.
50. ODOT. Work Zone Traffic Analysis Manual. [Online] 2007. [Cited: 6 14, 2016.] http://library.state.or.us/repository/2007/200711261146561/index.pdf.
51. FHWA. Work Zone Safety Website. [Online] 2016. [Cited: 6 14, 2016.] https://www.workzonesafety.org/files/documents/SWZ/DC_PC_case_study.pdf.
52. USDOT. *Developing and Implementing Transportation Management Plans for Work Zones. FHWA-HOP-05-066.* Washington, D.C. : s.n., 2005.
53. Ozbay, K., Wang, H., Bartin, B., Kurkcu, A. and Maggio, M. *Highway Repair Consolidation Feasibility, FHWA-NJ-2016-002.* 2016.
54. FHWA. Crash Reduction Factors. [Online] [Cited: 8 2, 2016.] http://safety.fhwa.dot.gov/tools/crf/.

APPENDIX A – INTERVIEW QUESTIONS

General Questions

(These questions are applicable to all the agencies and are intended to identify roles and responsibilities, and examples, in coordinating work zones projects.)

General Questions

1) Describe the main work zone projects that your agency/unit controls. Can you provide a list of current work zones and planned ones?
2) Do you maintain a database of your upcoming projects?
3) Do you have an organizational chart or a similar document that help control the scheduling of work zones? Please describe the process.
4) How do you disseminate work zone information to road users? What methods are used to inform the drivers and what type of traffic control tools are used for this purpose?
5) What traffic operations functions that you perform currently being executed are mandated by law? Which are guided by policy? What are the constraints that control scheduling of work zones?
6) How are work zones organized with the cooperation of different departments inside your agency? What kind of partnerships with other agencies is established in coordinating road projects? How are the roles of partners defined?
7) Does your agency use any tool for planning and managing work zones?
8) How does the agency predict impacts on roadway network? Do you use sophisticated traffic simulation methods? What safety measures are used in work zones? Can you provide a list of studies/reports?
9) What are the impacts of Vision Zero and Drivers First programs in the development of strategies in work zone scheduling?
10) What procedures are used to coordinate special events, such as games, festivals and marathons?

Specific Questions

Focus: Planning, Operational, Strategic

- Do these agencies manage their investments to accommodate individual needs of city DOT at a regional level?
- How do they collaborate with other state agencies to develop cooperation strategies?
- How do they develop policies to deal with work zones?
- What are the special strategies that are used to reduce impact of work zones?
- How do they set internal priorities in making investment decisions among different needs and programs?

- What's the impact of Vision Zero and recent safety concerns in the development of strategies to coordinate work zones?

Other Stakeholders (discuss these topics during interview if possible)

- **Community Boards:** appointed advisory groups from various districts throughout each of the five boroughs of New York City. Composed of 50 volunteer members, each appointed by the local Borough President.

  http://www.nyc.gov/html/cau/html/cb/cb.shtml
- **Business Improvement Districts (BID):** formal organizations made up of property owners and commercial tenants who are dedicated to promoting business development and improving an area's quality of life.

  http://www.nycbidassociation.org/
- **General Public:** any pedestrian, road user, public that may be affected by work zones.