Participant Workbook

SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

SHRP 2 Renewal Project R11

Participant Workbook

ACKNOWLEDGMENT

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TABLE OF CONTENTS

Introduction

This course is designed to provide participants with a basic working knowledge of the Work Zone Impact and Strategy Estimator (WISE) software tool. The training discusses the features of the WISE program as well as proper use and application. Limitations of the tool and valid parameters for inputs are also important components.

Executive Summary

The U.S. highway system is aging and must be rebuilt while we are driving on it and living next to it. Research in the SHRP 2 Renewal focus area therefore addresses the need to develop a consistent, systematic approach to completing highway projects quickly and cost-effectively while simultaneously minimizing, managing, and mitigating disruption to the community and adjacent land uses. Over the last several years, the transportation planning community has begun using the concept of corridor and network management to describe the current status and future needs for transportation improvements. However, the transportation corridor and network analysis at the planning stage may not consider the impact that renewal projects may have on existing traffic. The analysis may not consider the impact that different maintenance of traffic strategies can have on the overall budget, disruption to traveling public, disruption to commerce, and impacts on the local community during construction of the program of improvements. Decisions made during planning may not fully recognize the redistribution of traffic due to restrictions or closures, may not adequately recognize or mitigate disruptions, and may not minimize costs in contractor overhead, materials, or the driving publics' user costs. These decisions may also overlook opportunities to minimize both the number and the duration of construction or maintenance stoppages. It is the purpose of this project to provide the tools and training necessary to close this gap.

The overall WISE (Work Zone Impact and Strategy Estimator) is a software program in two parts, but functioning under a single graphical user interface (GUI). WISE GUI is the link between the WISE Planning Module and the WISE Operation Module. The WISE GUI links these tools using a WorkSpace concept. A single WorkSpace gathers the metadata necessary to define a network, multiple projects, variables, and scheduling data needed to successfully perform an evaluation of a given scenario in the Operation and Planning modules.

Course Outcomes

At the end of this course, participants will be able to
- Define WISE and explain its purpose and application.
- List and explain the limitations of the WISE program.
- Identify and explain system requirements of the WISE tool.
- Identify and explain the minimum data requirements for the WISE tool.
- Create a WISE WorkSpace or open an existing WorkSpace.
- Explain the process for importing a transportation network into WISE.
- Explain the process for importing basic traffic information into WISE.

- Understand and explain the input of planning characteristics, including seasonal factors, start/end of program, value of time, analysis periods, and project description.
- Explain how to build the WISE strategies library.
- Understand and explain how to enter, and the distinction between, demand-based and duration-based strategies.
- Understand and explain the input of project information, including project name, earliest/latest end dates, project duration, project precedence, project link, and project construction cost.
- Explain the selection of demand-based and duration-based strategies for each project.
- Understand and explain the three types of traffic diversion present in the WISE tool.
- Understand and explain the project information tools in WISE.
- Explain the WISE validation functions prior to sequencing.
- Understand, at a high level, the WISE sequencing algorithm.
- Understand and be able to explain the results of the WISE sequencing algorithm.

- Understand, at a high level, the traffic operation program's function in the WISE architecture.
- Understand the interaction between the planning and operation functions of WISE.
- Understand, at a high level, the dynamic traffic assignment function of traffic operations software.
- Explain the substitution of DTA diversion in WISE and the re-running of the sequencing algorithm.

Course Schedule

Day One

Time	Lesson Title	Length (mins)
8:30 – 9:15	Welcome and Introductions of Instructors and Participants	(:45)
9:15 – 9:30	Completion of Registration Paperwork	(:20)
9:30 – 10:00	Session 1: Introduction to WISE	(:30)
10:00 – 10:20	Break	(:20)
10:20 – 11:30	Session 2: Getting Started in WISE	(:70)
11:30 – 12:00	Session 3: Creating/Opening a WorkSpace	(:30)
12:00 – 1:00	Lunch	(:60)
1:00 – 2:30	Session 4: Planning Module (Inputs)	
	▪ Importing a Network	(:15)
	▪ Importing Traffic Information	(:15)
	▪ Planning Characteristic Inputs (Seasonal Factors, Start/End of Program, Value of Time, Road User Costs, Analysis Periods, Project Description)	(:60)
2:30 – 2:50	Break	(:20)

Time	Lesson Title	Length (mins)
2:50 – 4:20	Session 4: Planning Module (Inputs) (Cont'd)	
	▪ Building Your Strategies Library	(:20)
	▪ Demand-Based Strategies	(:35)
	▪ Duration-Based Strategies	(:35)
4:20 – 4:30	Day 1 Wrap-Up	(:10)

Day Two

Time	Lesson Title	Length (mins)
8:30 – 8:45	Day 1 Review	(:15)
8:45 – 10:00	Session 4: Planning Module (Inputs) (Cont'd)	
	o Inputs of Project Information	
	▪ Project Name; Earliest/Latest End Dates, Project Duration	(:15)
	o Project Precedence	(:20)
	o Project Link (Capacity/Speed/Number of Lanes)	(:20)
	o Total Project Construction Cost (Day/Night)	(:20)
10:00 – 10:20	Break	(:20)
10:20 – 12:00	Session 4: Planning Module (Inputs) (Cont'd)	
	o Selection of Project Strategies	(:45)
	o Traffic Diversion (User Supplied/WISE Supplied/Traffic Operation Software)	(:40)
	o Project Info Tools	(:15)
12:00 – 1:00	Lunch	(:60)
1:00 – 2:15	Session 5: Running the Algorithm	
	o Validation of the Planning WorkSpace	(:30)
	o The WISE Sequencing Algorithm	(:45)
	o Executing the Process	
2:15 – 2:35	Break	(:20)
2:35 – 4:15	Session 5: Running the Algorithm (Cont'd)	
	o Display/Interpretation of Results	(:55)
	o Optimization of Project Sequence	(:45)
4:15 – 4:30	Day 2 Review and Conclusion	(:15)

Day Three

Time	Lesson Title	Length (mins)
8:30 – 8:45	Day 2 Review	(:15)
8:45 – 10:00	Session 6: Operation Module (Traffic Operations Software)	
	o The Hand-off Between Planning & Operation	(:15)
	o Transmodeler, DynusT, or Other Operational Software	(:60)
10:00 – 10:20	Break	(:20)
10:20 – 12:00	Session 6: Operation Module (Cont'd)	
	o Dynamic Traffic Assignment (DTA)	(:50)

	o Running a WISE Project in Traffic Operations Software	(:50)
12:00 – 1:00	Lunch	(:60)
1:00 – 2:15	Session 7: Back to the Planning Module	
	o Automatic Population of Operations Diversion in Planning	(:30)
	o Re-run of Sequencing Algorithm	(:45)
2:15 – 2:35	Break	(:20)
2:35 – 3:00	Applications of WISE and Review	(:25)
3:00 – 4:30	Case Study Wrap-up/Review/ Conclusion	(:90)

Slide 1

Work Zone Impact and Strategy
Estimator (WISE)

WISE

1

Slide 2

Classroom Protocols

- Be on time.
- Questions and participation are essential.
- Parking lot concept.
- Respect class schedule—and others!
- Complete all paperwork.
- Attend all sessions.
- Limit distractions.

2

Slide 3

Course Organization

- Seven sessions focusing on
  – The capabilities and limitations of WISE

  – The capabilities and limitations of the Planning function

  – The capabilities of the Operation function

  – The interaction between Planning & Operation

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Slide 4

SESSION 1:
INTRODUCTION TO WISE

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Slide 5

What is WISE?

- The Work Zone Impact and Strategy Estimator (WISE) is
  - A Software Engine in Two Parts

    - A Planning Engine (Project Sequencing Optimization)

    - An Operation Engine (Existing Traffic Operational Platform)

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Slide 6

The Purpose of WISE

- To produce a project sequence intended to

  - Manage Disruption to the Traveling Public
  - Manage Disruption to Adjacent Land Uses
  - Present Estimated Program Costs
  - Allow Comparison of Program Alternatives

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Slide 7

Applications of WISE

- Can be applied to any size network

- Can be applied to any complex corridor

- Can accommodate unlimited projects

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Slide 8

Limitations of WISE

- WISE has numerous validations built in
- Inputs must fall within valid parameters
- To utilize WISE, the user must have
  - A network formatted for traffic operational software such as DynusT or Transmodeler

  - Traffic volumes formatted for the network

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Slide 9

**SESSION 2:
GETTING STARTED IN WISE**

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Slide 10

System Requirements

- x86-compatible processor
- Microsoft® Windows® XP (32-bit), Windows Server® 2003 (32-bit), Windows Server 2008 (32-bit), Windows Vista® (32-bit), Windows 7 (32-bit)
- 128MB of RAM

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Slide 11

Minimum Data Requirements

- Link – Node Network with Basic Geometry

- Basic Traffic Flow Numbers

- NEXTA utilizes .xml Spreadsheet Formats

- Additional Data can be utilized, if available

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Slide 12

Getting a Dataset Into WISE

- The procedure for dataset conversion is
  1. Export the network from planning software [comma delimited (.csv)]
  2. Copy Link/Node information
  3. Copy Zone/Control information

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Slide 13

GUI Tools

- Inputs are a variety of numerical, text, and "radio-button" features.

- NEXTA is the graphical network editor.

- Validation checks exist on each tab.

- Final Planning Validation checks all inputs

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Slide 14

**SESSION 3:
CREATING/OPENING A WORKSPACE**

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Slide 15

The Initial Screen

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Slide 16

A WorkSpace Must Be Identified

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Slide 17

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Slide 18

Name & Save WorkSpace

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Slide 19

SESSION 4:
PLANNING MODULE (INPUTS)

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Slide 20

Ready to Import Analysis Area

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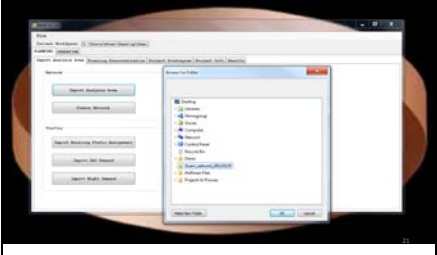
Slide 21

Navigate to NEXTA Network

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Slide 22

Import Your Static Demand Table

Slide 23

Select and Open

Slide 24

NEXTA View of Imported Network

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Slide 25

Enter Seasonal Factors

Slide 26

Specify Renewal Program Start/End

Slide 27

Specify the Analysis Periods

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Slide 28

Enter Road User Costs

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Slide 29

Enter a Program Description (Opt.)

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Slide 30

Validate Your Entries

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Slide 31

Build Your Strategies Library

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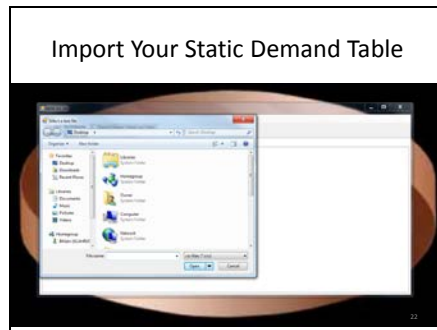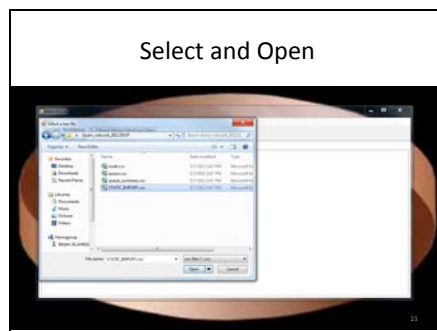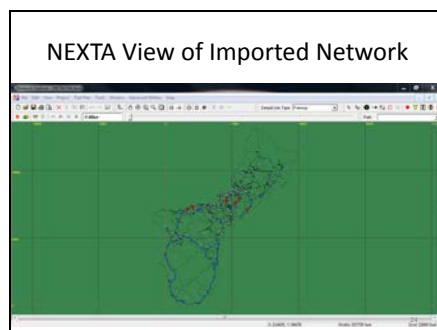
Slide 32

Strategies to Reduce Demand

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Slide 33

Inputs Must Be Within Valid Ranges

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Slide 34

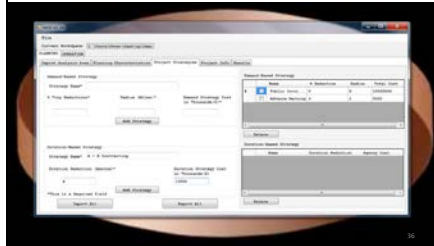**Save Each Strategy Individually**

Slide 35

A Limitless Number of Strategies
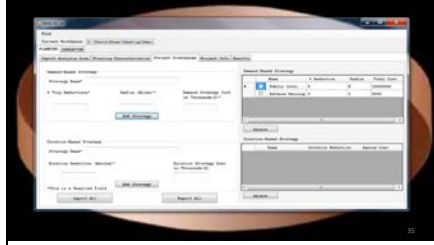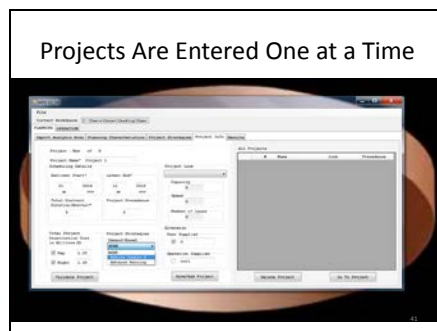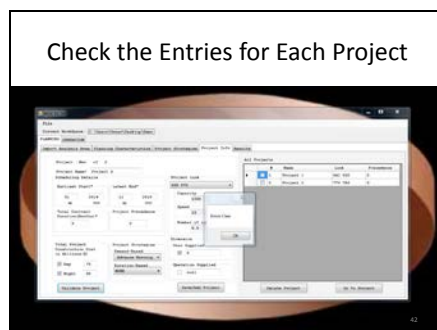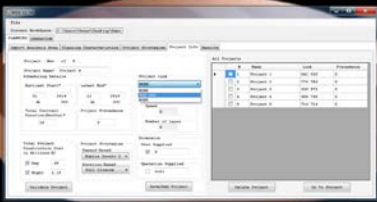

Slide 36

Strategies to Reduce Duration

Slide 37

Save Individual Duration Strategies

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Slide 38

Entered Strategies Can Be Exported

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Slide 39

Navigate to Project Info Tab

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Slide 40

Work Zones in NEXTA

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Slide 41

Projects Are Entered One at a Time

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Slide 42

Check the Entries for Each Project

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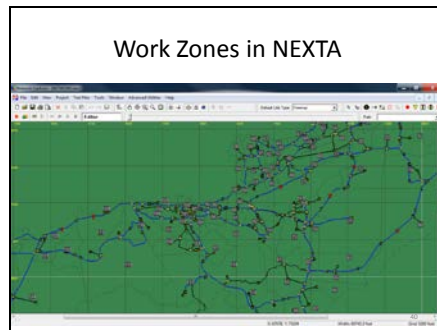
Slide 43

1:1 Relationship Between Projects & Links

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Slide 44

Projects Can Be Deleted or Modified

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Slide 45

SESSION 5:
RUNNING THE ALGORITHM

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Slide 46

Navigate to Results Tab

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Slide 47

Final Validation Check

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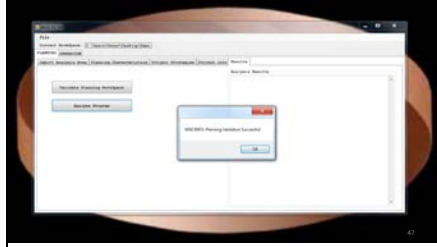
Slide 48

Combinatorial Sequencing Engine

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Slide 49

Analyze Program

Slide 50

A Final Validation Check

Slide 51

The Algorithm Is Called Into Action

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Slide 52

TABU Methodology

Slide 53

Stability Is Reached

Slide 54

Results in Right Pane

Slide 55

Project Sequence in
Chronological Order

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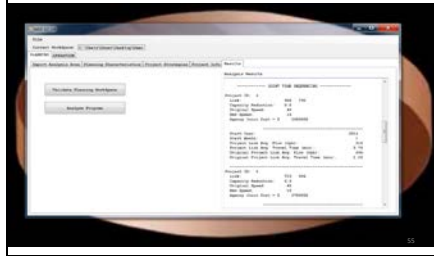
Slide 56

Optimization of Sequencing

- Project Info may be updated any time.

- Different combinations of strategies may be
  selected.

- Project precedence may be set.

- Resequence may happen any number of times.

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Slide 57

**SESSION 6:
OPERATION MODULE**

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Slide 58

Planning/Operation Hand-Off

- Project Info is automatically populated in Operation.

- The same network data are utilized.

- The same traffic information is utilized.

58

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Slide 59

The Hand-Off

- Base Network Geometry is carried over.

- Base Traffic Information is carried over.

- Diversion Estimates are NOT carried over.

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Slide 60

The Operation Tab

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Slide 61

Operational Software

- Select a Simulation Software Package.

- Estimates the evolution of systemwide traffic flow dynamics patterns resulting from drivers seeking the best routes; traffic responds to changing network demand/supply conditions.

JMM1

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Slide 62

JMM1

Dynamic Traffic Assignment (DTA)

- Supplements existing travel forecasting models and microscopic simulation models.

- Allows modeling of dynamic traffic across a range of scales from corridor to regional.

- Allows capturing of complex and dynamic interactions between various entities.

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Slide 63

The Base Scenario

- Runs DTA
  - Across the entire network
  - For all projects
  - WITHOUT work zones present

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Slide 64

Run the Base Scenario

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Slide 65

Running the Base Scenario

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Slide 66

Now Run Individual Projects

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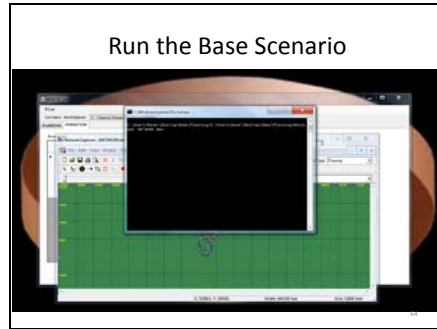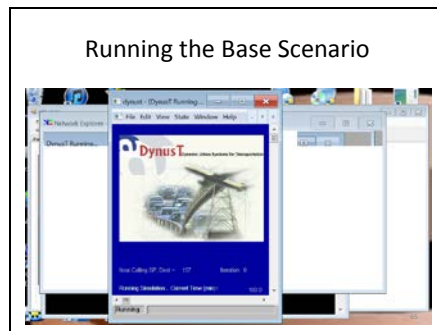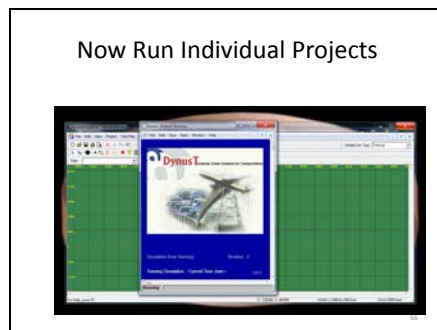
Slide 67

Running Individual Projects

- Isolates a single project.

- Runs DTA for diversion analysis WITH JMM1
  - The work zone in place.

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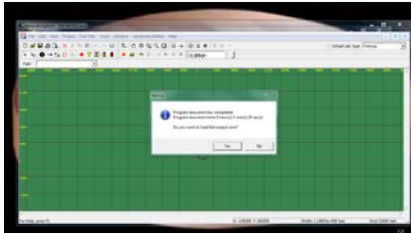
Slide 68

Simulation Run From NEXTA

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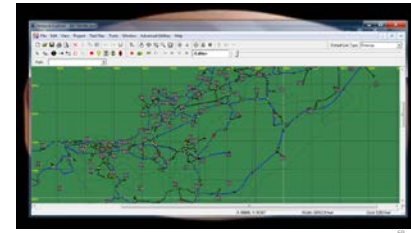
Slide 69

Only One Project Active

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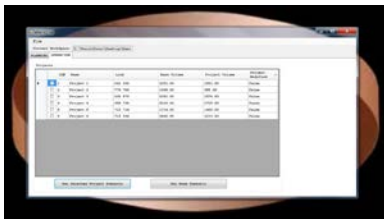
Slide 70

Project Volumes Loaded & Saved

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Slide 71

SESSION 7:
BACK TO THE PLANNING MODULE

Planning Module

Operation Module

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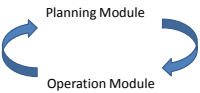
Slide 72

Return to Planning/Project Info Tab

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Slide 73

Select Operation Supplied Diversion
and Save

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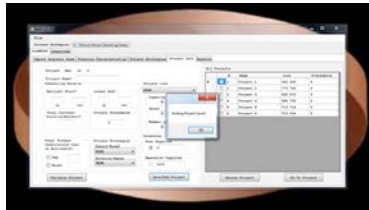
Slide 74

Rerun Sequencing Algorithm

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Slide 75

New Sequencing Results Displayed

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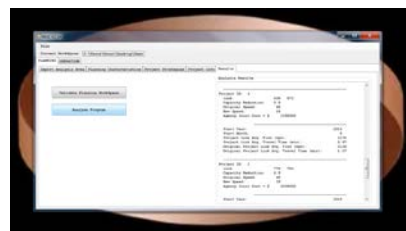
WORK ZONE SEQUENCING

Mathematical formulation

Given a set of work zone projects, the objective is to find a feasible project schedule such that the overall resultant generalized cost – including user and agency costs – is reduced to the minimum level. Let $\mathbb{P}$ be a set of projects subject to schedule, and $\mathbb{S}$ be the feasible set of schedule of $\mathbb{P}$, and denote by $p(i, j, k)$ an individual project schedule, that project i is open (namely in construction) at month j with construction mode k . Denote by $P :=$ $\{p(i, j, k)\}$ a combination of $p(i, j, k)$ that consists of a feasible schedule of $\mathbb{P}$ such that $P \in \mathbb{S}$. Let x_a be the link flows on link a with no work zone implementation (before scenario), and $t_a(x_a)$ be the corresponding link travel time; let x_a' be the redistributed flows on link a considering traffic diverge due to P (after scenario), and $t_{a,P}(x_a')$ be the resultant link travel time. Given a time horizon T such that all projects must be completed before T, the objective is to find a pool (or combination) of $p(i, j, k)$, namely $P \in \mathbb{S}$, such that the resultant total traffic delay, plus the agency cost implementing P, is minimum among the entire T. The work zone schedule (WZS) problem is formulated as follows.

Notations
Sets:
$\mathbb{P}$	A set of projects, $\mathbb{P}$ = { i } ,
$\mathbb{S}$	Feasible set of schedule of $\mathbb{P}$,
W	A set of O-D pairs, W = { w } ,
R_w	A set of routes between O-D pair $w \in W$,

Parameters:
d_w	Demand for O-D pair w,
τ	Month index, $\tau = 1,2, \dots, T$,
T	Time horizon,
k	Construction mode, referring daytime construction, or nighttime, or both,
$c(i, j, k)$	Agency cost expensed to construct project i staring at month j with a mode of k,
VOT	Value of time,

Variables:
P	One instance of schedule of $\mathbb{P}$, P = $\{p(i, j, k)\}$ that consists of a combination of $p(i, j, k)$,
$p(i, j, k)$	An individual project schedule that project i starts at month j with a mode of k,
x_a	Link flows with no work zone construction,
x_a'	Link flows with work zone construction,
$t_a(x_a)$	Link travel time with link flow x_a,
$t_{a,P}(x_a')$	Link travel time with link flow x_a' resulted by P,
f_r^w	Flows along route r between O-D pair w , with no work zone

$$f'^{w}_{r} \qquad \text{construction,}$$

f'^{w}_{r} Flows along route r between O-D pair w, with work zone construction,

δ^{w}_{ar} 1 if link a belongs to route r between O-D pair w, 0 otherwise.

WZS: $P = argmin_{P \in \mathbb{S}} \sum_{\tau=1}^{T} \left(\sum_{a} \int_{0}^{x'_a} t_{a,P}(\omega)\,d\omega - \sum_{a} \int_{0}^{x_a} t_a(\omega)d\omega \right) \cdot VOT$

                     $+ \sum_{i \in \mathbb{P}} c(i,j,k)$ (1)

s.t.

$$x'_a = \sum_{w \in W} \sum_{r \in R_w} f'^{w}_{r} \cdot \delta^{w}_{ar} \qquad \forall a \in A \qquad (2)$$

$$x_a = \sum_{w \in W} \sum_{r \in R_w} f^{w}_{r} \cdot \delta^{w}_{ar} \qquad \forall a \in A \qquad (3)$$

$$\sum_{r \in R_w} f'^{w}_{r} = d_w \qquad \forall w \in W \qquad (4)$$

$$\sum_{r \in R_w} f^{w}_{r} = d_w \qquad \forall w \in W \qquad (5)$$

$$f'^{w}_{r} \geq 0 \qquad (6)$$

$$f^{w}_{r} \geq 0 \qquad (7)$$

$$P = \{p(i,j,k)\} \in \mathbb{S} \qquad (8)$$

      Two types of cost are evaluated in the objective function, i.e., user cost and agency cost. User cost is measured by the user travel time among all links in the network; we use VOT to convert the user travel time into monetary dollars. Agency cost measures the out-of-the-pocket dollars to implement the work zone construction with a specified mode. The first term of objective (1) is to minimize the summation of offset of travel time before and after the work zone construction among the entire horizon. Such an offset of travel time expresses the traffic delay caused by the work zone construction. The second term of objective (1) is the corresponding agency cost expensed to implement work zone schedule P. It is noteworthy that some project schedule may reduce the user cost delay significantly; however, the matching agency cost to implement such a schedule might be expensive too. For instance, constructing a major freeway/arterial in nighttime could save user time delay greatly, for the peak demand occurring in the daytime does not get impacted. However, it also cost the agency to spend much more money to implement such construction strategy.

      Constraints (2) – (7) stand for the conventional traffic assignment formula, with and without work zone construction respectively. The first term in (1) ideally needs to call for a set of traffic assignment runs to evaluate traffic diverge involved in different combinations of $p(i, j, k)$, so virtually the problem is a combinatorial optimization problem which ideally requires traffic assignment runs for all possible

combinations of work zone schedules, which is obviously intractable. To solve WSZ, we suggest applying a heuristic method rather than comparing all possible combinations in a brute-force way. The key component is how to evaluate the traffic impact due to work zone construction. The WISE functionalities require a fast pass to evaluate traffic impact with high resolution. In this regard, we propose to estimate traffic diverge among a set of competitive paths, as discussed in detail in the following sections.

Solution Approach

Neighborhood search

The heuristic starts from any feasible solution, e.g., initializing all work zone projects at the first month at a feasible mode, that is regarded as the current local solution. The goal is to search an improved local solution in each iteration. Based upon the given solution, we compute the monthly-specific traffic performance that varies due to each of work zone implementation and seasonal demand. Consider three projects as an example in Figure 1, where it plots the initial solution. Suppose the length of three given projects is 3, 4, and 5 months if constructed in daytime (or nighttime), respectively. In Figure 1, the traffic performance in each month varies due to not only monthly-specific travel demand, but also the network construction imposed by the presented work zone project schedule.
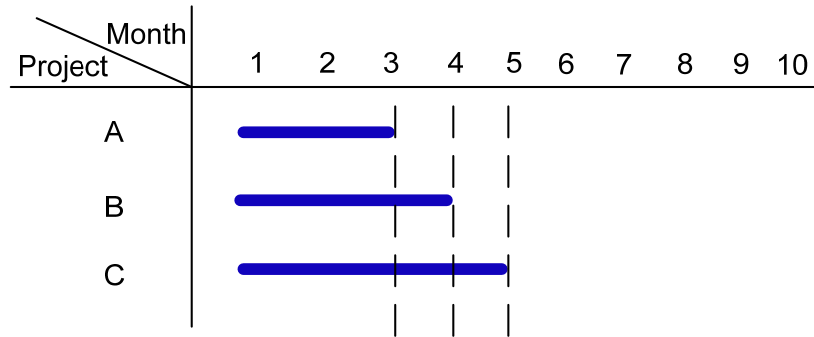

Figure 1. An initial solution

The algorithm then examines all possible/feasible schedule choices for each project. In each iteration, we inspect each feasible starting time of each project and evaluate the resultant travel time accouting for traffic diverge. The procedure is illustrated in Figure 2.

Month / Project	1	2	3	4	5	6	7	8	9	10
A	○	○	○	○	○	○	○	○	○	○
B	○	○	○	○	○	○	○	○	○	○
C	○	○	○	○	○	○	○	○	○	○

○   Start time of current feasible schedules

○   Start time of feasible schedules that will be evaluated
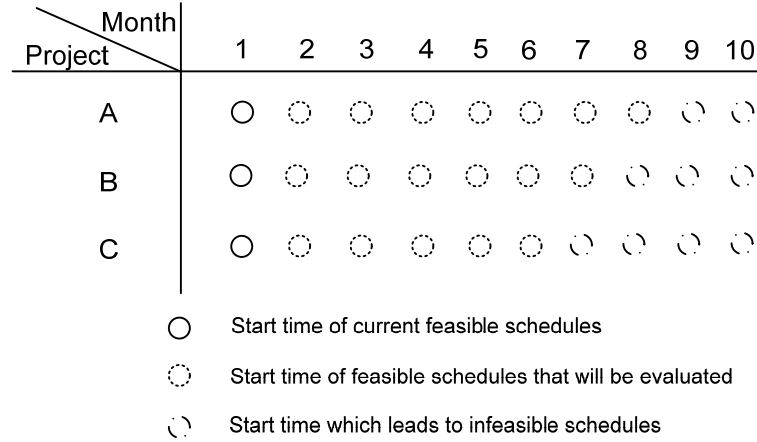
○   Start time which leads to infeasible schedules

Figure 2. Search domain in the heuristic

Assume the total horizon of interest is 10 months; the holes with solid circles symbolize the feasible starting schedule when work zone construction begins. A "neighborhood search" is performed to determine the impacts of each work zone at every month subject to the current feasible schedule. At this stage of the solution, in neighborhood search there are two iterative loops. The outer loop iterates every single project one by one at a fixed start time, and the inner loop iterates *every other* single project's starting point (dotted circles in Figure 2) for each of the corresponding single projects. That is, two loops screen every circled hole in the legend shown in Figure 2, and in each screen we compute the resultant network-wide travel time, by assuming the screened project is scheduled at the screened starting time, if such a starting time is feasible. We then evaluate the resultant user cost plus agency cost that is summed among the whole time horizon – e.g., 10 months in the example shown in Figure 2.

After the outer- and inner- loops screening all the (feasible) circles in Figure 2, we select the min-screen that is with the minimal "total-time horizon-cost" (user cost plus agency cost). If the cost leads to a saving, we reschedule the corresponding project start to construct at the month that is identified by min-screen, and add the solution in a Tabu list before proceeding to the next iteration. By this step we move from one feasible solution to another, as shown in Figure 3, where the min-screen is to schedule, say, Project B of Figure 3, to start at month 5 and it leads to a cost saving. Solutions in the Tabu list are restricted in the next few iterations so as to avoid being trapped at a local optimum. In the next iteration, we continue outer- and inner- loops of screening, and so on. The algorithm stops until no improvement could be found, or certain amount of iterations have been reached (stop criteria).
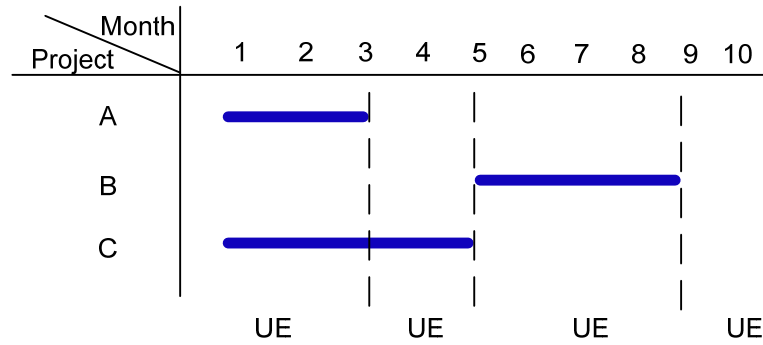
Figure 3. Move to another feasbile schedule

Seasonal demand factor

WISE supports the monthly-specific travel demand that leads to the monthly-specific travel time in the network wide. If modelers have traffic volume data on links produced by their own external travel demand model (TDM), they can import those traffic volumes from TDM to WISE. Otherwise, the modelers have an option to define the benchmark travel demand, and WISE can trigger the self-contained traffic assignment module to produce traffic volume on links based upon the user equilibrium assignment. WISE then uses a set of user-defined seasonal factors to adjust the equilibrium volume to produce the seasonal monthly-specific traffic volume data.

Demand reduction factor

Similar with the seasonal factor, demand reduction factor also adjusts the network traffic volume in the demand side. Agencies usually broadcast a heads-up announcement following the policy and/or legislative procedure, which may reduce the local travel demand nearby the projects. Given the inputs of an impact radius and a factor, we firstly identify the link flows whose origin is within the radius of the work zone project, and then adjust that portion of link flows by producing the factor.

Construction modes

The work zone sequencing problem investigated [here] supports different construction modes, classified by constructing in (1) daytime only, (2) nighttime only, and (3) both. Following the daytime and nighttime construction modes, we consider two sets of demand tables, day demand and night demand. Different construction modes come with variant demand inputs to obtain the link volume, and variant agency cost – typically construction at nighttime budgets much more agency cost than in daytime.

We extend the neighborhood search framework discussed above slightly, to take into account of three construction modes, as follows. Create three search domain tables in Figure 2, representing constructing in daytime only, nighttime only, and both, respectively.

In each iteration, we screen three tables, instead of just one table, and select the feasible solution with the minimal user cost plus agency cost among all alternative-screening in three tables.

Precedence sequence

It is common that several work zone projects may exhibit precedence sequence relationship, e.g., certain project must be constructed before/after another one. It is rather straightforward to bear the precedence constraint in the neighborhood search framework. Since we evaluate each possible screening for each of project one by one, we first check whether the current screening (e.g., schedule the project starting at the screened month in the specific mode) is feasible to meet the precedence constraint or not, provided that the schedules of all other projects (except the screened one) are given and fixed. If it meets the precedence constraint, then the algorithm continues to evaluate the resultant user and agency's costs; otherwise we simply mark the current screening infeasible and continue to the next screening.

**Evaluate network-wide travel time accounting for traffic diverge**

Ideally the traffic impact in the network involved in each screening calls for traffic assignment run, which is obviously computational intractable even though traffic assignment runs in modest time in the state-of-the-art commercial software, due to the large amount of screening in the neighborhood search framework. In this research, we propose to diverge traffic from the congested work zone route to a set of competitive routes, with a purpose to assess traffic impact due to work zone construction at a fine level in a quick manner.

Identify a set of competitive routes

We apply k-shortest path (k-SP) algorithm to produce a set of alternative diverge routes competing to the route passing the work zone link. The assumption is that traffic diverge or reassignment due to work zone construction is restricted to the set of competitive routes.

The research of k-SP could be categorized as ranking SP routes (Azevedo et al. 1994; Martins 1983), loopless routes (Yen 1971), node-disjoint routes (Suurballe 1974), and arc-disjoint routes (Suurballe and Tarjan 1984). Those k-shortest paths studied in literature either use SP ranking algorithm to find routes that have the least cost but very similar, or find node-disjoint or edge-disjoint paths which are dramatically different between each other. To evaluate traffic diverge in the work zone domain, we desire to find a set of k-shortest paths with no significance of similarity. In this regard, we introduce the penalty function in a revised SP ranking algorithm, with forbidden of repeated links or nodes. The purpose is to obtain k-shortest paths with less similarity.

Given a work zone link (or subpath), denoted by (i,j), we first identify a set of nodes upstream the work zone link, denoted by s, and identify a set of nodes downstream, denoted by t. s and t can be established by a simple search method, and supposedly $s \cap t = \emptyset$. The distance between any node in s and i shall be restricted no more than a user-defined radius, d, and the distance between any node in t and j shall be no more than d. The assumption is that most traffic reroutes are restricted to diverge at d miles upstream of the work zone link, and merge d miles downstream; this is consistent with our observation that most traffic diverge occurs nearby the work zone link. We then create an extended network $\mathcal{N}$ as follows. Create a supersource p and connect p to all nodes in s with zero length (or travel time), and create a supersink q and connect all nodes in t to q with zero length. Delete the work zone link (i,j) in $\mathcal{N}$, for the purpose of identify alternative routes not traversing (i,j). Now we are ready to apply the k-SP algorithm to find k ranked shortest paths from p to q in the network $\mathcal{N}$. Paths satisfying the following two conditions consist of the set of competitive routes: (1) produced by the k-SP algorithm; and (2) travel time is shorter than the one passing the work zone link. The concept is demonstrated in Figure 4. It is noteworthy that the design of solving k-SP in $\mathcal{N}$ is to let the algorithm determine the appropriate diverge and merge points of the competitive routes, rather than pre-define them arbitrarily (see Figure 4(b)).
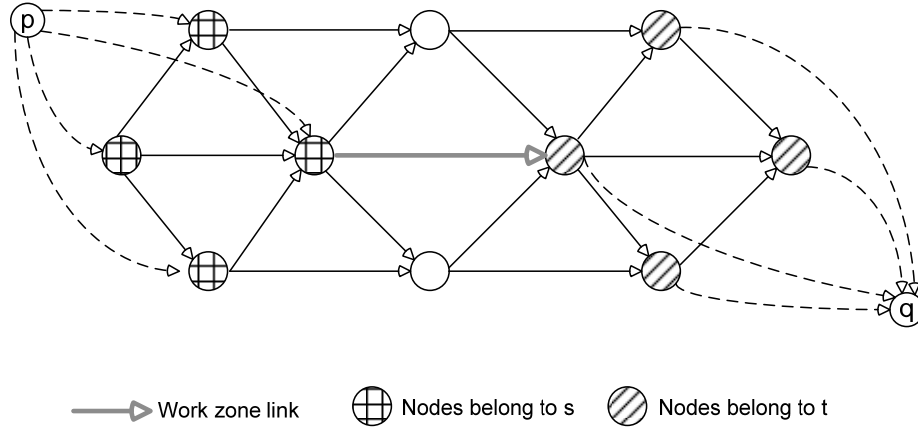
(a) Construction of network $\mathcal{N}$

Competitive routes – – – ▷ Routes passing the work zone
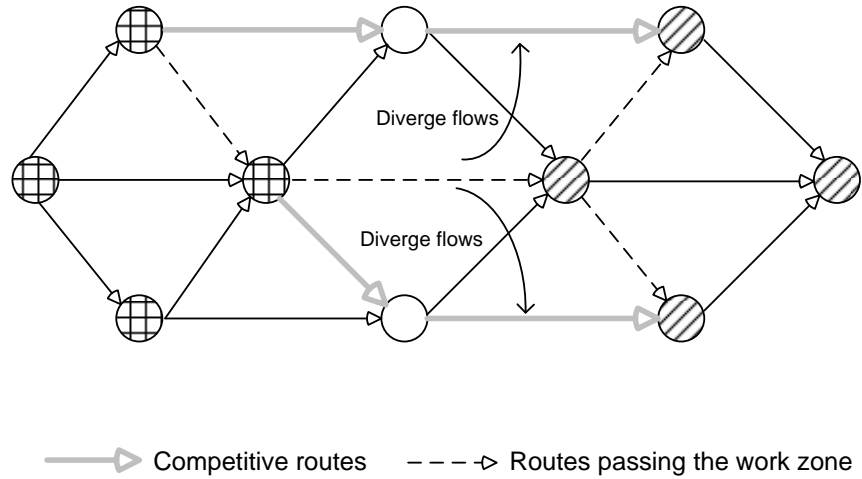
(b) Generate competitive routes

Figure 4. Demonstration of generating competitive routes

K-SP algorithm

We apply a revised version of the ranking algorithm to solve k shortest paths in $\mathcal{N}$, based on the work of (Martins 1983). The flow chart of the algorithm is depicted in Figure 5.
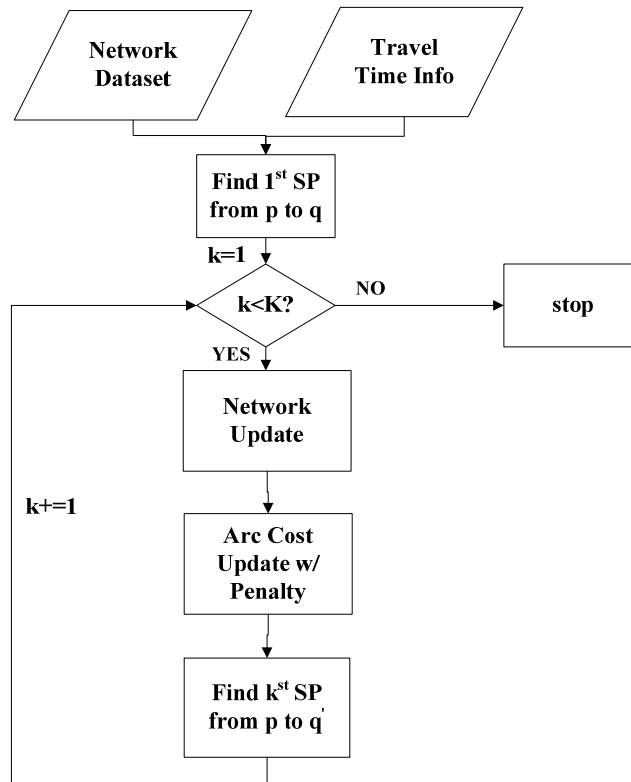
Figure 5. Flow chart of k-SP algorithm

Step 1: Initialization

Read the network structure and travel time information into the memory, construct the adjacency list for the nodes within the network.

Step 2: Find the first SP

Find the first Shortest Path from the given source to the sink. It would not matter which SP algorithm is used. Dial's implantation of Dijkstra algorithm or A* algorithm is suggested for this one-to-one SP problem.

Step 3: Stop criteria

If k paths are found, stop; continue otherwise.

Step 4: Network update

Update the network based upon the SP found in the last iteration, denoted by p. Find the first node n_1 in p with multiple incoming arcs, let (n, n_1) be the arc belongs to p. Delete arc (n, n_1) in $\mathcal{N}$. This procedure ensures that the next path found in $\mathcal{N}$ must differ from p. For all arc $(i, j) \in p$, let the cost c_{ij} be the original cost times a user defined penalty factor, PF. That is, $c_{ij} \leftarrow c_{ij} \times PF$. This penalty factor is designed to reduce the similarity, i.e., we have incentive to find a new path with less chance to use the same arc used by the paths found before.

Step 5: Find the next SP on the updated network

The algorithm guarantees to find a different route from others that have been found in the previous (k-1) iterations.

Shift flows to competitive routes

After the k-SP step, we obtain a set of competitive routes and the corresponding routes passing the work zone link. Let $\underline{p}$ be one of the competitive route and $\underline{x}, \underline{t}$ be its flow and travel time (namely cost), respectively. Let $\overline{p}$ be the route passing the work zone link with respect to $\underline{p}$, and $\underline{x}, \underline{t}$ be its flow and travel time, respectively. From the definition of competitive-route-set there is $\underline{t}(\underline{x}) < \overline{t}(\overline{x})$. We then shift Δx units of flow from the long path $\overline{p}$ to the short one $\underline{p}$, such that the travel time along two routes are the same – indicating an equilibrium – after traffic diverge (flow shifting), i.e., $\underline{t}(\underline{x} + \Delta x) = \overline{t}(\overline{x} - \Delta x)$.

Δx could be determined by Newton method. Linearize the path-costs difference:

$$\bar{t}(\bar{x} - \Delta x) - \underline{t}(\underline{x} + \Delta x) \approx \bar{t}(\bar{x}) - \bar{t}'(\bar{x})\Delta x - \underline{t}(\underline{x}) - \underline{t}'(\underline{x})\Delta x = 0. \qquad (9)$$

It solves for Δx:

$$\Delta x = \frac{\bar{t}(\bar{x}) - \underline{t}(\underline{x})}{\bar{t}'(\bar{x}) + \underline{t}'(\underline{x})}. \qquad (10)$$

Note that the flow shifting between one pair of routes may impact the travel time of the other routes, so this shifting procedure should be conducted in an iterative manner.

Overall algorithm procedure

In summary, the neighborhood search algorithm proposed to solve the WZS is summarized in Figure 6 below.

Algorithm: Neighborhood search to optimize work zone sequencing

Input: network, flows on the network, a set of work zone projects, entire time horizon

Step 1: Initialization

    Set each project an initial feasible schedule.

Step 2: Neighborhood search

    For k in each construction mode: daytime only, nighttime only, and both:

        For i in each project:

            For j in each month:

                If schedule project i to start at month j with a mode of k is feasible:

                    Do traffic diverge.

                    Compute the objective of Eq. (1).

                    If it results in a reduced objective, schedule project i starting from month j with construction mode k, update the corresponding solution;

                    Add triple (i, j, k) into Tabu list, and restrict this solution in the next few iterations (user defined).

                Otherwise: continue

Step 3: Check stop criteria

    Stop if a predefined maximal iteration number is reached, or in continuous 5 interations it does not find a solution with improved objective.

Step 4: Return the solution with the minimum objective that has been found.

Figure 6. Flow chart of the work zone sequencing algorithm

Session 6 – Operation Module

SESSION 6: OPERATIONS MODULE (DYNUST)

Planning/Operations Hand-off

- Project Info is automatically populated in Operations.

- The same network data is utilized.

- The same traffic information is utilized.

The Hand-Off

- Base Network Geometry is carried over.

- Base Traffic Information is carried over.

- Diversion Estimates are NOT carried over.

The Operations Tab
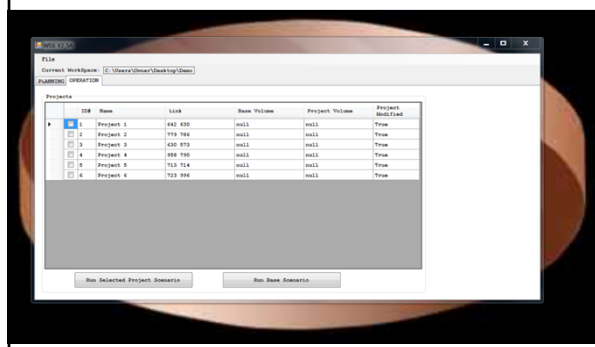
DynusT

- DynusT is a simulation-based dynamic traffic assignment (DTA) software.

- Estimates the evolution of system-wide traffic flow dynamics patterns resulted from drivers seeking the best routes traffic responds to changing network demand/supply conditions.

Dynamic Traffic Assignment (DTA)

- Supplements existing travel forecasting models and microscopic simulation models.

- Allows modeling of dynamic traffic across a range of scales from corridor to regional.

- Allows capturing of complex and dynamic interactions between various entities.

The Base Scenario

- Runs DTA across:
  - The entire network
  - For all projects
  - WITHOUT work zones present

Run the Base Scenario
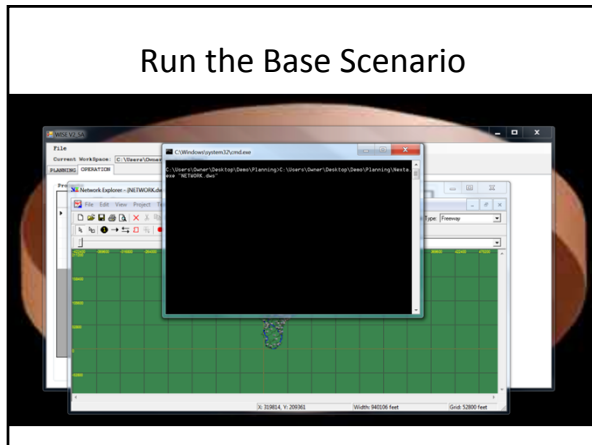
Running the Base Scenario
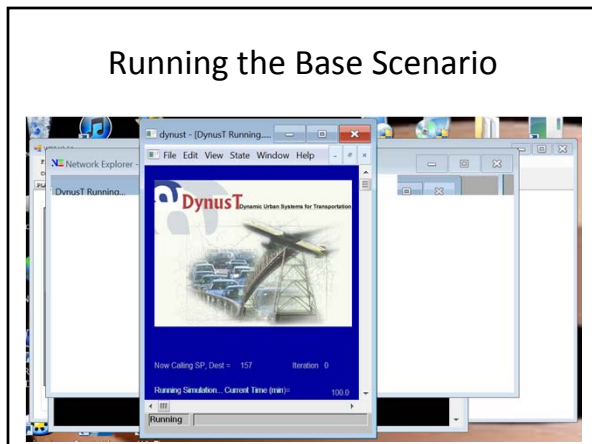
Now Run Individual Projects
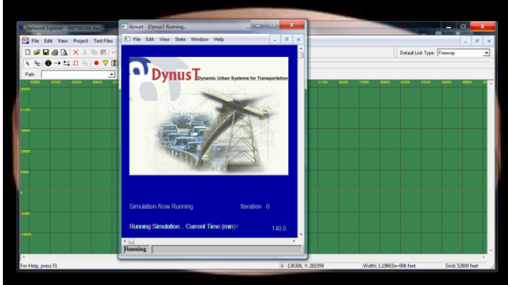
Running Individual Projects

- Isolates a single project.

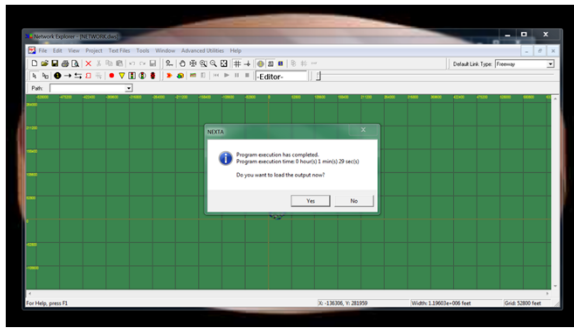- Runs DTA for diversion analysis WITH
  – The work zone in place.

Simulation Run From NexTA

Only One Project Active
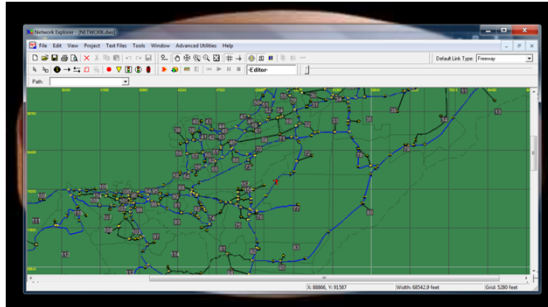
Project Volumes Loaded & Saved
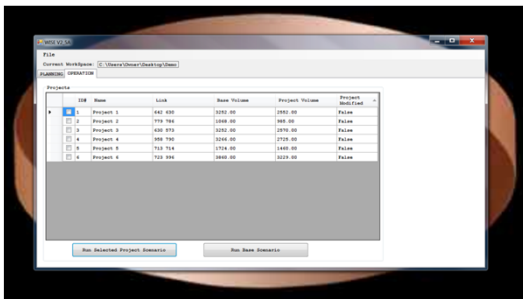
Dynamic Traffic Assignment (DTA) models have become a viable modeling option. DTA models supplement existing travel forecasting models and microscopic traffic simulation models. Travel forecasting models represent the static regional travel analysis capability, whereas microscopic traffic simulation models are superior for dynamic corridor level travel analysis. DTA models fill in the gap by enabling dynamic traffic to be modeled at a range of scales from the corridor level to the regional with expanded and unique functional capabilities enabled by the DTA methodology.

The objective of static traffic assignment is to determine network traffic flows and conditions resulting from demand/supply interactions via route choices from travelers. Route choice behavior is based upon the assumption that all travelers are aimed at traveling from their origin to their destination with the least travel time. When every traveler succeeds in finding such a route, every used route has the minimum time or cost between its origin and destination; moreover, for each O-D pair, every route used has the same travel time. This condition is known as user optimal or user equilibrium.

Dynamic Traffic Assignment (DTA) is of a similar objective, but with a representation of time variations in traffic flows and conditions, thus attempting to reflect the reality that traffic networks. To represent these time-varying conditions in the context of user equilibrium, two concepts must be recognized: (1) in a dynamic approach, the user equilibrium condition of equal travel times on used routes applies only to travelers who are assumed to depart at the same time between the same O-D pair. This means the equilibrium condition is disaggregated to consecutive departure times instead of the entire analysis period. (2) Travel times on network links vary over time based on preceding experienced travel times as this will depend on when travelers arrive at the various links along a route.

Traffic assignment algorithms find these interactions to determine route and link volumes and travel times that satisfy this equilibrium condition through iterative procedures. At equilibrium, no traveler can find an origin–destination route that would lead to a reduction in travel time. If an equilibrium state is reached, it will persist as long as the network and travel demand do not change, because no travelers have any incentive to choose different routes.
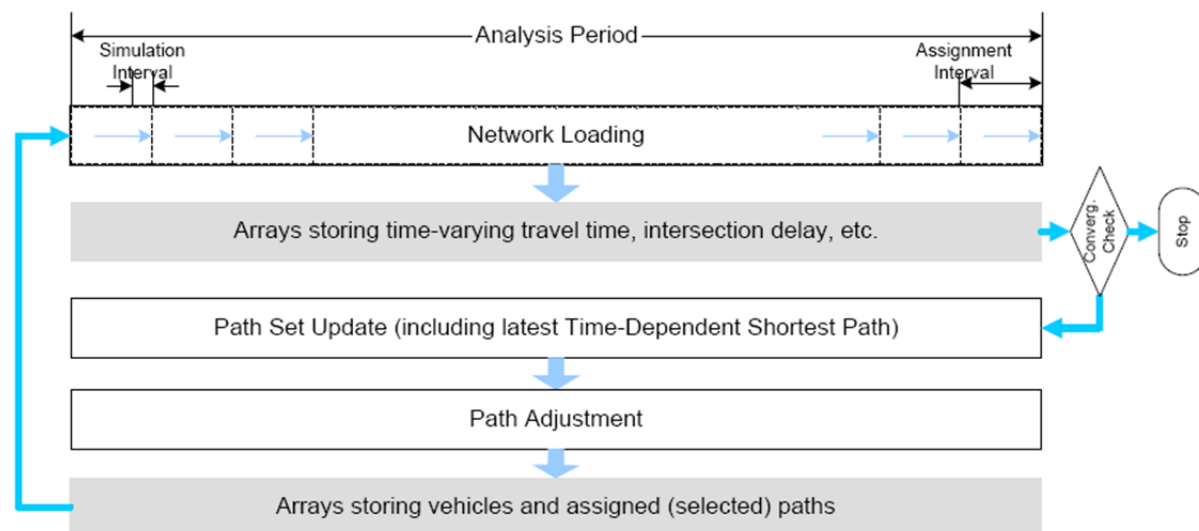
Dynamic network analysis models seek to provide another, more detailed means to represent the interaction between travel choices, traffic flows, and time and cost measures in a temporally coherent manner (e.g., further improve upon the existing time-of-day static assignment approach). More specifically, Dynamic Traffic Assignment (DTA) models aim to describe such time-varying network and demand interaction using a behaviorally sound approach. The DTA model analysis results can be used to evaluate many more meaningful measures related to individual travel time and cost, as well as system-wide network measures for regional planning purposes.
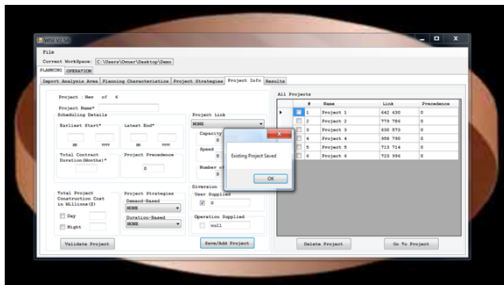
Session 7 – Back to the Planning Module
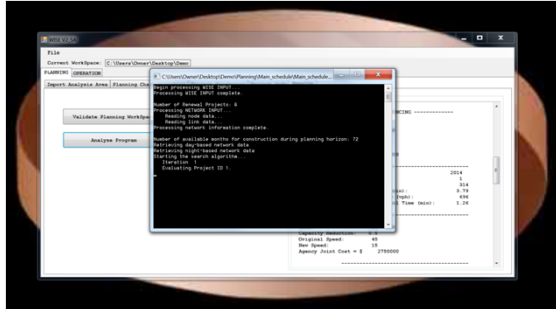
SESSION 7: BACK TO PLANNING MODULE

Planning Module

Operations Module
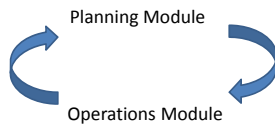
Return to Planning / Project Info Tab
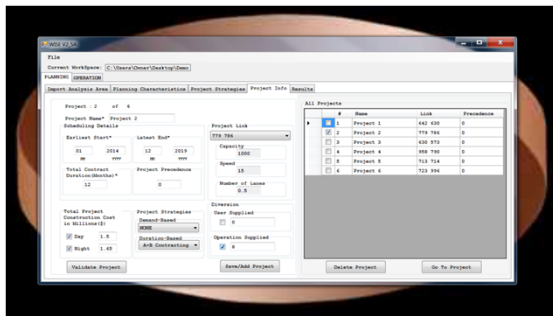
Select Operations Supplied Diversion & Save
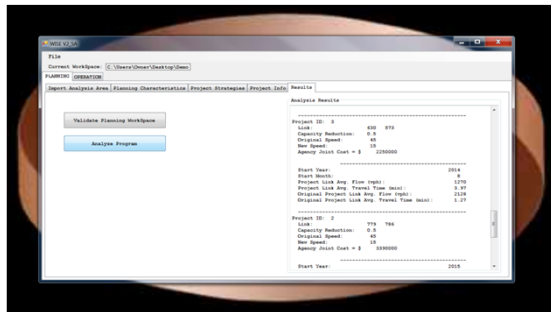
Re-Run Sequencing Algorithm

New Sequencing Results Displayed