2.0 Urban Freeway

2.X San Antonio, Texas: I-410

Key Observations

- **QuickZone can be utilized to define Road User Cost (RUC) values for A+B bidding accelerated construction projects.**
- **QuickZone can be utilized to define Incentive/Disincentive RUC values associated with construction milestones.**
- **The predicted delays and associated RUCs were used to optimize the construction sequencing to take into account not only constructability but also delay to motorists.**
- **Very large QuickZone networks can be efficiently constructed using Geographic Information Systems (GIS) software.**

2.X.1 Overview

The I-410 project consists of upgrading I-410 from Nacogdoches Road to Austin Highway to a ten-lane freeway, as illustrated in Figure 2.X.1, all in accordance with the latest federal, state and local regulations. This includes widening of freeway facilities including work related to grading, structures, base, surfacing, signing, pavement markings and coordination of traffic management systems and utilities.

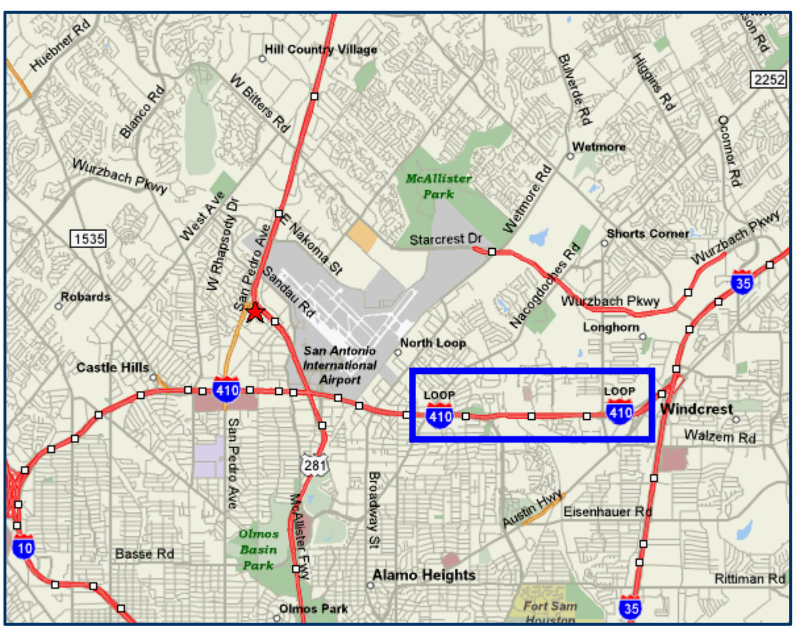


Figure 0.1 I-410 Project Area – San Antonio, Texas

I-410 provides major connectivity to a number of interstate facilities in the San Antonio area and access to important land uses such as San Antonio International Airport, Northeast Baptist Hospital, St. Mary's Hall School, Serna Elementary School, and Garner Middle School, among others. Congestion on I-410 is significant during both morning and afternoon peaks. Average Daily Traffic (ADT) on I-410 approximates 150,000 vehicles. In addition, parallel outer road provide access to a number of major arterials.

The Texas Department of Transportation (TxDOT) identified the need to widen I-410 to accommodate an increasing demand on the system. Due to the regional importance of the facility to vehicular flow, an accelerated construction delivery mechanism, entitled A+B bidding, is being considered. In essence A+B bidding entails submittal by prospective contractors of a project cost (A) and a duration in days to complete the construction (B). Associated with the B component is a Road User Cost (RUC) in dollars per day. In A+B bidding, the contract is awarded to the contractor who submits the lowest bid inclusive of construction cost (A) and delay cost (B). This often results in the selection of a contractor who can deliver the project at a lower cost AND do so while minimizing delay to the traveling public. Furthermore, in A+B bidding, a number of construction milestones in the construction sequencing are identified and a target incentive/disincentive (I/D) dollar value is associated with each. If the contractor delivers the milestone before the target date, he receives an I/D credit per day up to a pre-determined cap. Otherwise an I/D value per day late is charged to the contractor.

TxDOT utilizes a number of methods to arrive at the dollar value associated with the B component of A+B as well as for the I/D milestone values. The methods range from manual calculations related to capacity and delay to advanced traffic microsimulation for highly complex projects. The I-410 project was too complex for manual calculations and did not include a simulation component. Therefore, the need was articulated for a method significantly more robust than manual calculations without the expense of a detailed microsimulation model. At this juncture, it was proposed that QuickZone could be utilized to determine delays associated with the construction work zone and in turn to derive the RUCs needed for the A+B bidding framework.

As such, the role of QuickZone in this case study was to quantify the delays associated with each phase and/or segment of the construction sequencing plan, report RUCs for those milestones considered to be in the critical path and for which an I/D cost was needed, and report an average RUC per day for the entire project to be used to quantify the B component of the bidding strategy.

2.X.2 Network Design

It quickly became apparent that a significant challenge with using QuickZone for the I-410 project was the efficient construction of the project network. Given the extend of the facility, the outer road system, the number of interchanges, and the desire for coding additional geometry for alternate route investigations, the IH-410 model would be quite large in number of nodes and links. In addition, there were very limited resources in time and cost to produce the analysis. As such, it seemed not feasible to efficiently construct the network using the traditional hand assignment of nodes and links within QuickZone's Excel spreadsheets. A solution was devised using Geographic Information Systems (GIS) software as illustrated in the following paragraphs.

Network construction began with the importing of the project's design files in MicroStation format into ArcView 8.2, as illustrated in Figure 2.X.2. The ability to directly interface with the project's design files is of tremendous use to the modeler, as it facilitates incorporating changes to the model as the project progresses and geometry is modified, a process that is not as efficient with background images as the network building framework. Furthermore, design files are often correct in dimension and scale, eliminating the need to determine and account for scaling factors when building network geometry.

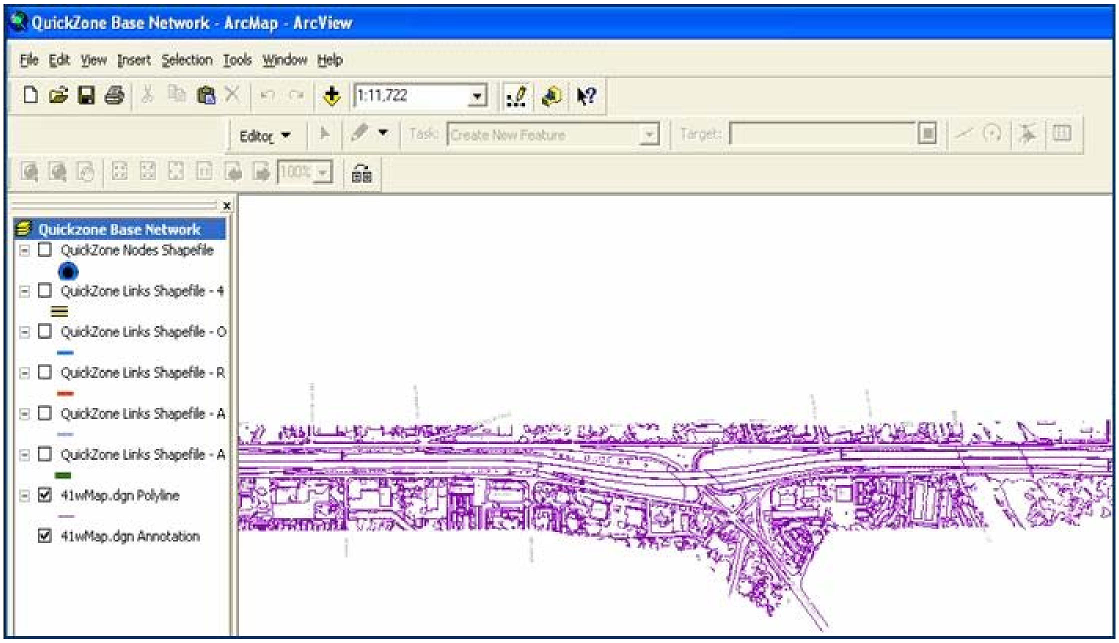


Figure 0.2 I-410 Project Design Files in ArcView 8.2

Subsequent to importing the design files, network construction proceeded with the addition of nodes and links to the network, as illustrated in Figure 2.X.3. This simple process entails a very fast digitization of nodes on top of desired junctions and links between nodes.

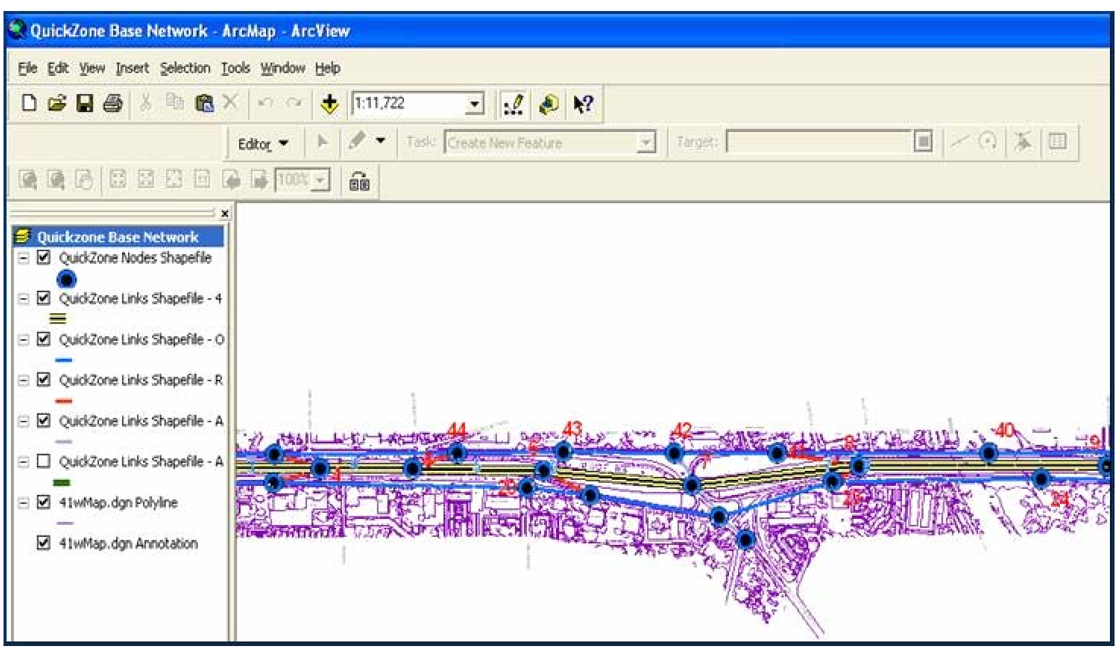


Figure 0.3 I-410 Project Nodes and Links

Due to the use of and ability to manipulate matrices, ArcView also presents an adequate platform for storing information about links and nodes. During the network building process, the attributes required by QuickZone were also coded into the attribute tables within the ArcView model, as illustrated in Figure 2.X.4.

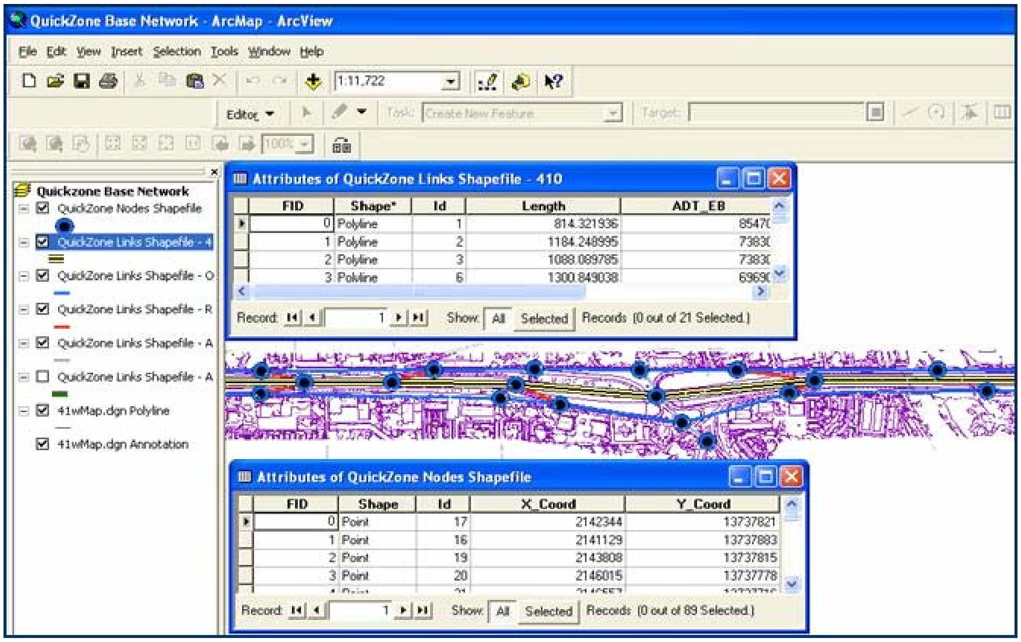


Figure 0.3 I-410 Project Node and Link Attributes

The most significant attributes for the nodes, as it relates to efficient network building for QuickZone networks, are the X and Y coordinate fields. With a simple Visual Basic routine, obtaining these values from ArcView is relatively instantaneous. Figure 2.X.4 provides a screenshot of the Visual Basic script for the X coordinates. A similar script was used to obtain an attribute critical to QuickZone links, link length.

Once all attributes were incorporated into the model's attribute tables, transferring all parameters to QuickZone was completed. This process highlights a fantastic feature of QuickZone – that it is based on Excel worksheets. This facilitates the transfer of information from other software and reduces what could be a complicated process requiring script writing to a simple cut-and-paste exercise. Figure 2.X.5 illustrates output from ArcView, which can be opened with Excel, used to transfer data to QuickZone.

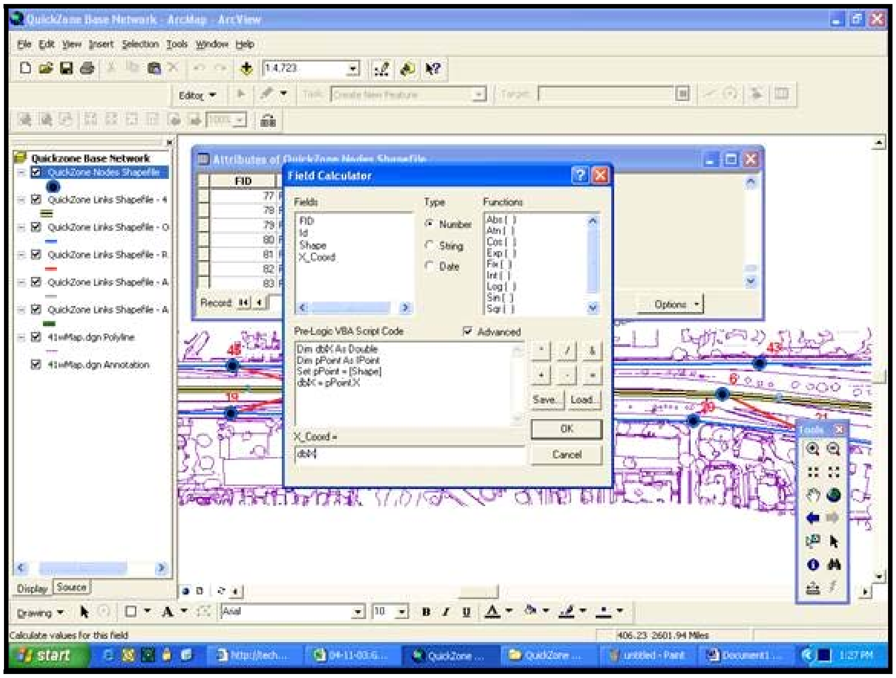
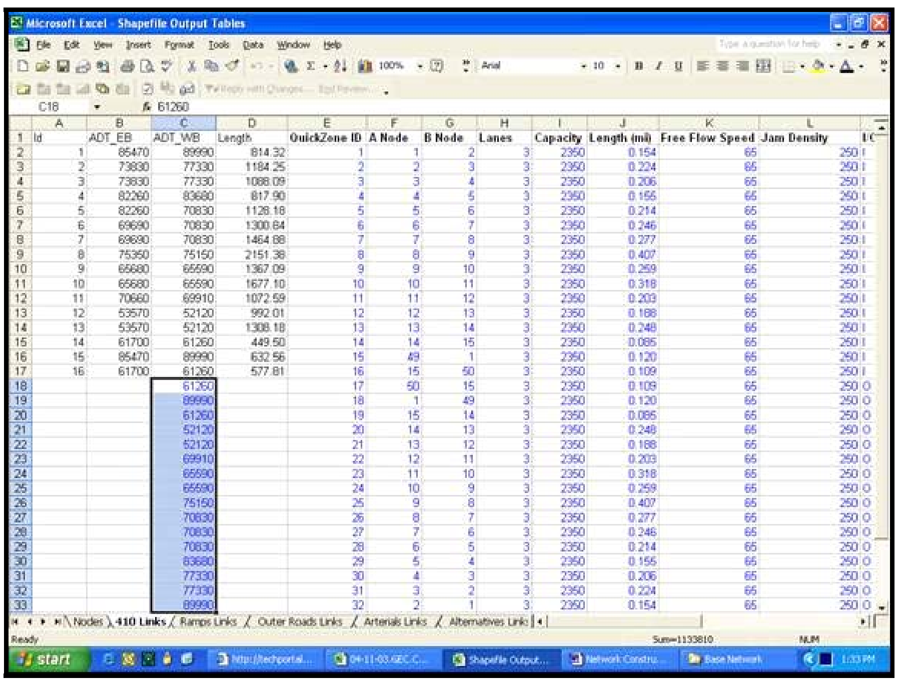


Figure 0.4 X-Coordinate Visual Basic Script



	A	B	C	D	E	F	G	H	I	J	K	L
1	Id	ADT_EB	ADT_WB	Length	QuickZone ID	A Node	B Node	Lanes	Capacity	Length (mi)	Free Flow Speed	Jam Density
2	1	85470	89990	814.32	1	1	2	3	2350	0.154	65	250 I
3	2	73830	77330	1184.25	2	2	3	3	2350	0.224	65	250 I
4	3	73830	77330	1088.09	3	3	4	3	2350	0.206	65	250 I
5	4	82260	83680	817.90	4	4	5	3	2350	0.156	65	250 I
6	5	82260	70830	1128.18	5	5	6	3	2350	0.214	65	250 I
7	6	69690	70830	1300.84	6	6	7	3	2350	0.246	65	250 I
8	7	69690	70830	1464.88	7	7	8	3	2350	0.277	65	250 I
9	8	75350	75150	2151.38	8	8	9	3	2350	0.407	65	250 I
10	9	65680	65590	1367.09	9	9	10	3	2350	0.259	65	250 I
11	10	65680	65590	1677.10	10	10	11	3	2350	0.318	65	250 I
12	11	70660	69910	1072.59	11	11	12	3	2350	0.203	65	250 I
13	12	53570	52120	992.01	12	12	13	3	2350	0.188	65	250 I
14	13	53570	52120	1308.18	13	13	14	3	2350	0.248	65	250 I
15	14	61700	61260	449.50	14	14	15	3	2350	0.085	65	250 I
16	15	85470	89990	632.56	15	49	1	3	2350	0.120	65	250 I
17	16	61700	61260	577.81	16	15	50	3	2350	0.109	65	250 I
18			61260		17	50	15	3	2350	0.109	65	250 O
19			89990		18	1	49	3	2350	0.120	65	250 O
20			61260		19	15	14	3	2350	0.085	65	250 O
21			52120		20	14	13	3	2350	0.248	65	250 O
22			52120		21	13	12	3	2350	0.188	65	250 O
23			69910		22	12	11	3	2350	0.203	65	250 O
24			65590		23	11	10	3	2350	0.318	65	250 O
25			65590		24	10	9	3	2350	0.259	65	250 O
26			75150		25	9	8	3	2350	0.407	65	250 O
27			70830		26	8	7	3	2350	0.277	65	250 O
28			70830		27	7	6	3	2350	0.246	65	250 O
29			70830		28	6	5	3	2350	0.214	65	250 O
30			83680		29	5	4	3	2350	0.156	65	250 O
31			77330		30	4	3	3	2350	0.206	65	250 O
32			77330		31	3	2	3	2350	0.224	65	250 O
33			89990		32	2	1	3	2350	0.154	65	250 O

Figure 0.5 Shapefile Output

The project's geometry, inclusive of the interstate alternate routes, is shown in Figures 2.X.6 and 2.X.7 in ArcView and QuickZone formats, respectively. Figure 2.X.8 illustrates a more detailed representation of the I-410 portion of the project geometry.

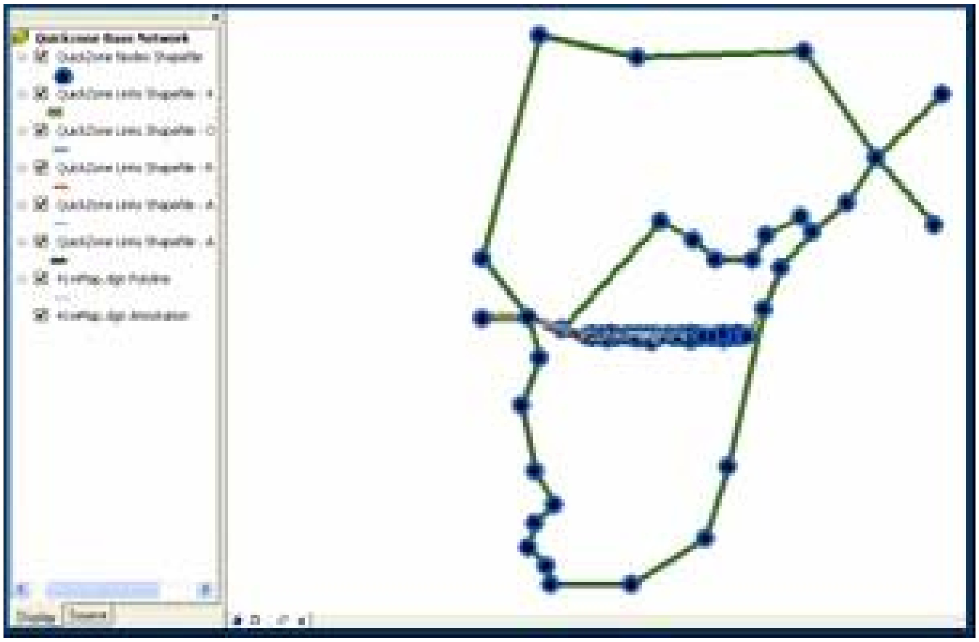


Figure 0.6 I-410 Project Network – ArcView

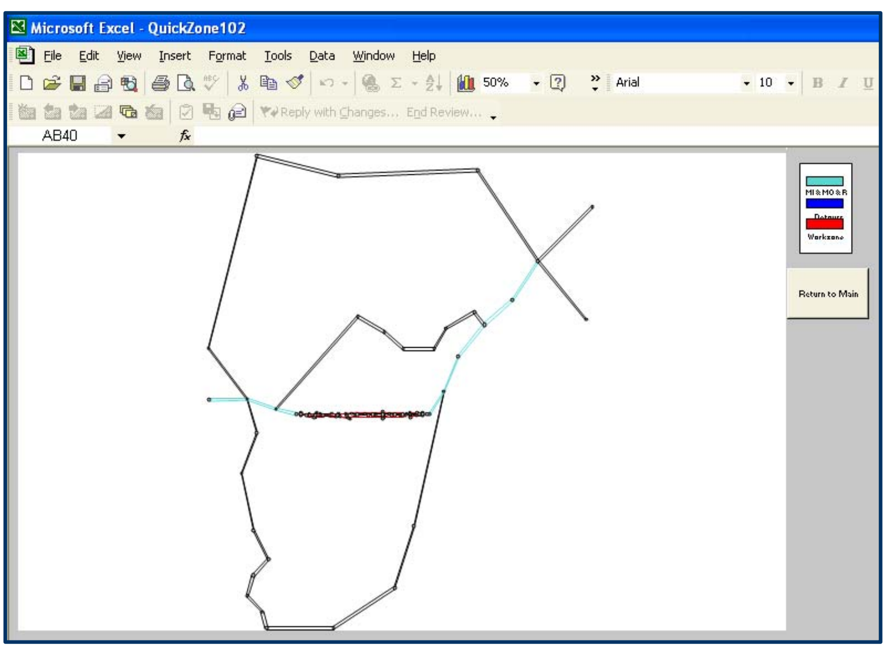


Figure 0.7 I-410 Project Network – QuickZone

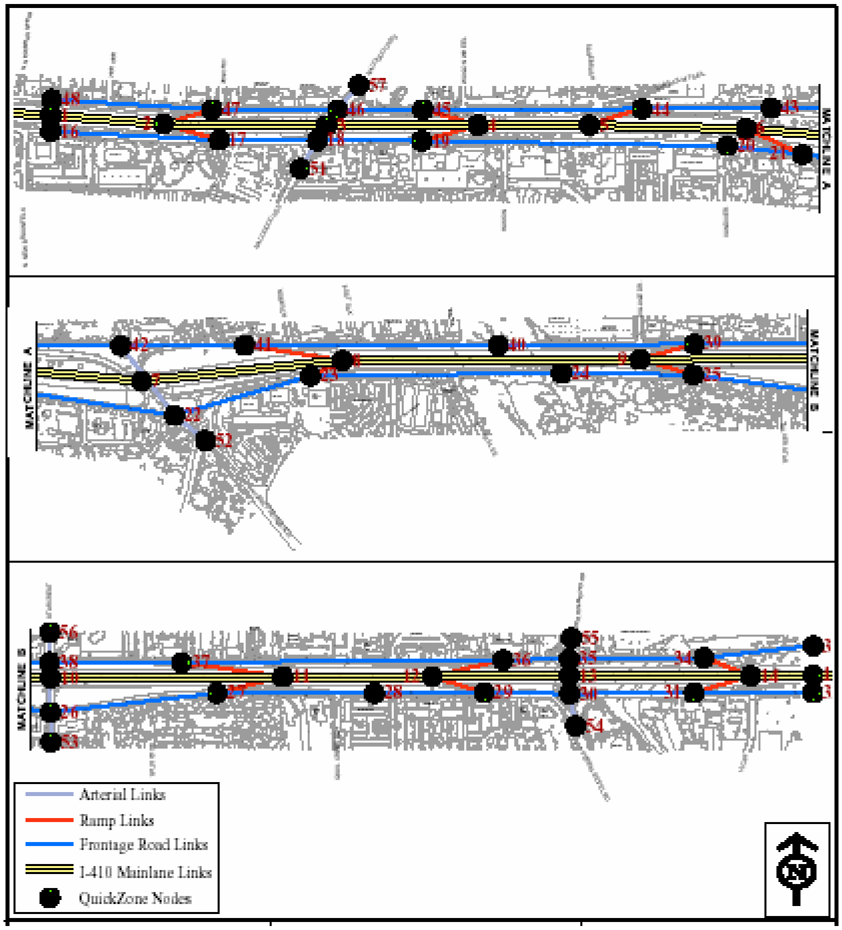


Figure 0.8 I-410 Project Network

2.X.3 Construction Phasing and Sequencing

Once the network demand, seasonal variations, and hourly distributions were input from a variety of volume sources, the analysis proceeded with a definition of the characteristics of the work zone. For this purpose, the project's phasing and sequencing plan was consulted to determine where and when capacity-reducing events would occur during construction. Items of interest included the location of the construction event, the resulting typical section changes, and the duration. Table 2.X.1 illustrates the duration of each capacity-reducing construction phase/stage combination. It is important to note that during accelerated construction of this type, work is ongoing for 24 hours each day.

Table 0.1 Capacity-Reducing Phase/Stage Durations

Capacity-Reducing Phase	Duration (Months)
Phase 1 – Stage 1	14
Phase 1 – Stage 2	9
Phase 2 – Stage 1	26
Phase 2 – Stage 2	10
Phase 2 – Stage 3	1
Phase 2 – Stage 4	2
Phase 3 – Stage 1	26
Phase 4 – Stage 1	15
Phase 4 – Stage 2	3
Phase 5 – Stage 1	24
Phase 5 – Stage 2	5

2.X.4 Capacity Reduction Calculations

In essence, each capacity-reducing phase/stage combination yielded a new typical section due to lane width reductions, shoulder width reductions, on shifting of the mainline from one side to the other to allow for reconstruction of bridges. For each resulting typical section, some which were common to a number of phase/stage combinations, a capacity reduction was calculated based upon Highway Capacity Manual "Adjustment Factor for Restricted Lane Width and Lateral Clearance" standards, engineering construction experience, and studies conducted on projects of this type. This resulted in a lookup matrix as illustrated in Table 2.X.2.

Table 0.2 Capacity Reductions for Typical Sections

CAPACITY REDUCTION FOR RESTRICTED LANE WIDTH AND LATERAL CLEARANCE		
ADJUSTMENT CODE	*TYPICAL SECTION*	*CAPACITY REDUCTION* [1]
AC-1	10-12-12-12-10	0
AC-2	1-12-12-12-10	129
AC-3	1-12-12-12-1	259
AC-4	10-10-11-10-10	588
AC-5	1-10-11-10-10	682
AC-6	1-10-11-10-1	987

Each of the above construction phases and stages impacts the capacity of a unique set of links on the I-410 mainline. Once all the capacity reductions associated with each phase/stage were calculated for each affected link, the reduction was coded into QuickZone for each sequencing element.

2.X.5 Delay Cost Parameters

Once a delay value was calculated for each phase/stage in the construction sequencing, the analysis proceeded with the calculation of road user costs. The cost of delay to road users incorporates the value of travel time for passenger vehicles and trucks independently. The 2001 delay costs were $16.24 and $24.49 for passenger cars and trucks, respectively, as reported in TxDOT's Accelerated Construction document. For this purpose a baseline 2001 cost for each of these vehicle types was projected to 2006 values by way of applying the Consumer Price Index (CPI) change from 2001 to 2006. As such, the following delay cost values were assumed in the analysis:

Table 0.3 Delay Cost Parameters

Vehicle Type	2004 Delay Cost ($/hour)
Passenger Cars	$18.19
Trucks	$24.49

A variable used by QuickZone to determine the life-cycle total cost of the project on a per year basis for the life of the improvements is inflation. According to the Office of Management and Budget, the forecasted inflation used in the development of the government's budget is projected to increase by 2.3% per year through 2008[1]. Therefore, an inflation factor of 2.3% per year was used in the development of the life-cycle costs of the project.

2.X.6 Results

Upon completion of network modeling, demand input, construction phasing, and delay parameter estimation, the QuickZone software reported queues, delays, and road user

[1] Office of Management and Budget of the United States Government (2004). *Economic Assumptions*. Retrieved November 15, 2004, from http:www.whitehouse.gov/omb/budget/fy2004/assumptions.html

costs associated with each phase/stage of the project work zone, as illustrated in Table 2.X.4.

Table 0.4 Road User Cost by Phase/Stage

Phase-Stage	Queue Weekly Max (mi)	Delay Weekly Max (min)	Cost Total ($Million)	Cost per day ($)
Phase 1 – Stage 1	0	0	0	0
Phase 1 – Stage 2	1.26	13.5	0.82	$13,016
Phase 2 – Stage 1	6.81	43.7	14.24	$78,242
Phase 2 – Stage 2	8.3	53.1	8.3	$118,571
Phase 2 – Stage 3	6.4	41.3	0.47	$67,143
Phase 2 – Stage 4	5.06	32.3	0.69	$49,286
Phase 3 – Stage 1	4.35	27.8	7.02	$38,571
Phase 4 – Stage 1	8.81	69.7	18.27	$174,000
Phase 4 – Stage 2	9.02	70.6	4.28	$203,810
Phase 5 – Stage 1	4.93	31.5	7.94	$47,262
Phase 5 – Stage 2	4.02	25.7	1.21	$34,571
		TOTAL =	**63.24**	

Of these phase/stage combinations, three were determined to be milestones. Additionally, a RUC was calculated for the project as a whole. Table 2.X.5 illustrates the values that would be reported in the Road User Cost document associated with the A+B contract documents. TxDOT current policy is to use 25% of RUC as an assignment of incentive/disincentive. It is very important to note that the analysis described herein is preliminary and will be refined as the design progresses.

Table 0.5 Road User Costs for A+B bidding

Milestone No.	Milestone Description	Average Road User Cost per Day	(1)Incentive /Disincentive Equivalence
1	Phase 2 – Stage 2	$118,571	$29,643
2	Phase 2 – Stage 3 **and** Phase 2 – Stage 4	$116,429	$29,107
3	Phase 5 – Stage 1 **and** Phase 5 – Stage 2	$81,833	$20,458
A+B	All Phases	$66,921	$16,730

(1)Incentive/Disincentive Equivalence is based on 25 percent of the daily road user cost.

2.X.7 Areas for Further Development

It is evident that QuickZone provides a very efficient method for the calculation of delay associated with work zones. Furthermore, the analysis above demonstrates that the software tool can be used for the specific application of calculating road user costs required for the definition of A+B accelerated construction projects. Some areas for further development are worthy of consideration, including:

1. With the availability of a new QZEditor software tool to build networks, it will become increasingly efficient to build large networks. Limitation do exist with this tool with respect to importing images for background and not design files, which would add benefit to the modeling process as noted earlier. Nevertheless, building large networks, a previously commonly-noted limitation with QuickZone is no longer an issue. Using the methodology described above, the physical network for I-410, without attributes, which included over 90 nodes and over 180 links was performed in less than two hours. It is likely that coding of the node X and Y coordinates manually into QuickZone would have alone easily exceeded this time frame.
2. The removal of the above limitation brings forth a new possible need for enhancement of QuickZone. It is now easy to envision a project that will require in excess of the 100 nodes and 200 links allowed by QuickZone. Therefore, expansion of these limits may be warranted.
3. With forthcoming enhancements to QuickZone's work zone development tools, it is likely that a more robust definition of the construction impacts will be possible.
4. Similarly, with the forthcoming enhancements to QuickZone's econometric variable tools that a more precise calculation of road user costs may be soon feasible.
5. Given QuickZone's ability to determine impacts to alternate routes, further analysis using this feature could be performed.
6. From a planning perspective, further investigations of QuickZone's travel demand management algorithms could also be conducted.

2.X.8 Contact Information

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