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GUIDANCE FOR FEASIBILITY ANALYSIS OF CANDIDATE SITES: HANDBOOK

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*TxDOT Project 0-5913: Feasibility of Speed Harmonization and Peak Period
Shoulder Use to Manage Urban Freeway Congestion*

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INTRODUCTION

The purpose of this handbook is to provide guidance in determining whether or not speed harmonization and peak period shoulder is feasible for a given site or set of sites. The content of this handbook is based on the analysis conducted for this project. Additional information regarding the topics presented in this handbook can be found in project report 0-5913-1, *Speed Harmonization and Peak-Period Shoulder Use to Manage Urban Freeway Congestion*.

The guidance for conducting feasibility analyses, presented below, primarily integrates the cost benefit analysis framework and the operational and deployment strategy presented in Chapter 8 of the project report. The collective goal is to intelligently apply speed harmonization and peak period shoulder use as a combined traffic control strategy that delays the onset of severe congestion and increases throughput. Guidance for assessing the feasibility of speed harmonization and peak period shoulder use is organized into six analysis components. These are:

- 1) Identify candidate sites;
- 2) Construct and run microscopic and mesoscopic simulation;
- 3) Identify infrastructure improvements;
- 4) Develop an enforcement strategy and public education plan;
- 5) Apply cost benefit analysis framework; and
- 6) Consider potential qualitative impacts.

Guidance for executing each of the feasibility analysis components is below.

IDENTIFY CANDIDATE SITES

Candidate sites should be selected based on their potential to benefit from speed harmonization and peak period shoulder use deployment. To identify sites with the most potential benefit for these strategies, an initial round of candidate sites or corridors can be identified based on the severity of the reoccurring congestion during peak commuting hours. This initial group of candidate sites can then be screened and simultaneously prepared for deployment by following the six steps noted above. Congested corridors (i.e., candidate sites) can be identified using existing TxDOT resources and monitoring processes.

CONSTRUCT AND RUN SIMULATION ANALYSIS

Microscopic and mesoscopic simulation analyses are necessary to develop and evaluate the optimal speed harmonization and peak period shoulder use traffic control schemes for a given corridor or candidate site. The simulation allows multiple schemes to be tested to determine the strategies best able to improve performance measures such as travel time, travel time reliability, safety, emissions, and vehicle fuel consumption.

When speed harmonization and peak-period shoulder use is implemented on the candidate freeway section, it affects traffic operation in the transportation network at two levels. The immediate effect is the change in traffic stream characteristics (speed, travel time, throughput, safety, etc.) of the freeway section where such strategies are implemented. Depending on the

specific changes in traffic operations, it may either create “induced demand” for the candidate freeway segment or may divert traffic from the candidate freeway to alternative routes. These changes are likely to affect traffic flow of feeder routes and parallel routes. In this manner, the effect of speed harmonization and peak-period shoulder use are likely to have an impact on the network as well as the freeway segment on which it is deployed.

Microscopic simulation is the preferred tool to study the effect of traffic management strategies on a specific roadway section in detail. Mesoscopic simulation is used to study the effect at the network level.

VISSIM (PTV AG) microscopic simulation software is used for corridor level study in this project. VISSIM is chosen because of its ease of use and the flexibility it provides to model complex traffic management strategies through its Vehicle Actuated Program (VAP) module. VAP provides the necessary tool to code real-time implementation of variable speed limit and dynamic shoulder use while the simulation is running.

Mesoscopic models are less data intensive and are preferred tools to study network level effects on large scale. VISTA (VTG Inc.) is chosen for mesoscopic simulation to study the network level effects of speed harmonization and peak-period shoulder use. The research team has prior experience in using VISTA and it has also developed a mesoscopic model of Austin, TX in VISTA, as shown in Figure 1. Therefore, VISTA was chosen as the mesoscopic simulation software for this project.

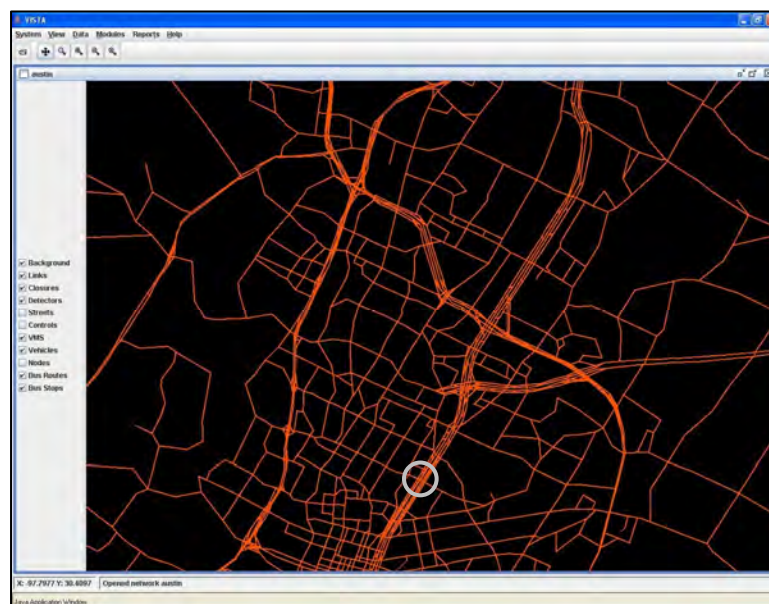


Figure 1. Snapshot of VISTA model for Austin, TX

Figure 2 shows a snapshot of the circled area in Figure 1. This circled area illustrates a microscopic simulation with the mesoscopic model using VISSIM.

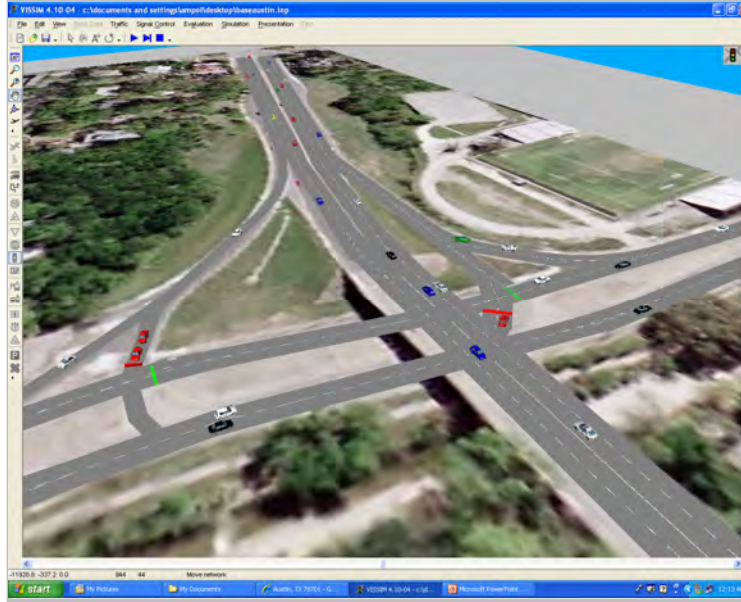


Figure 2. Snapshot of the circled area in Figure 1 in VISSIM

The following subsections discuss how to design an effective speed harmonization and peak period shoulder use scheme as well as how to quantify each of the performance measures noted.

Designing Appropriate Speed Harmonization and Peak Period Shoulder Use Schemes

Traffic simulation plays a crucial role in the design of speed harmonization and peak period shoulder use schemes. Hence, after the selection of a potential corridor, the first step of the analysis is to build a detailed simulation model, both of the local network (for microsimulation purposes), as well as for the “global” network (for mesoscopic simulation purposes). Table 1 summarizes the data requirements for modeling.

Table 1. Data Requirements for Modeling

Microscopic Model	Mesoscopic Model
Network topology for the candidate freeway—geometry, number of lanes, on-ramps, off-ramps	Network topology for the study area—all major freeways and arterial network
Demand—volume counts on mainline and ramps; or origin-destination travel demand data	Demand—origin-destination travel demand data
Speed limits on mainline and ramps	Capacity and free flow speed for all roadways

Depending on the availability of sufficient ITS technologies, there are two forms of speed harmonization: online and offline. If ITS deployment is sufficiently dense, then the online version is preferred. When there is not sufficient ITS deployment, offline algorithms are used. Many control algorithms have been proposed in the literature; however, as we have argued in Chapters 4 and 5 of the project report, simple control strategies are preferred. The online and offline control strategies are summarized next (for more details refer to Sections 4.2 and 4.3 of the project report).

To state the offline algorithm, let us first introduce some notation. In the following, let

\bar{u}_s = space mean speed

n = the number of segments the selected test corridor is to be divided (parameter that can be experimentally determined with microsimulation)

$q(k)$ = flow at road segment k in vehicle per hour

$c(k)$ = capacity of road segment k

Offline Algorithm Speed Harmonization

Input (\bar{u}_s, q) -curves for each of the n road segments for time t of the day

Output “Speed-harmonized road segments” for time t of the day

Step 1 Pick the most downstream road segment k for which the flow almost reaches capacity.

Step 2 FOR all road segments $r = k-1, k-2, \dots, 1$

DO select a speed for segment r such that $q(r) < c(r+1)$
set $c(r) \leftarrow q(r)$

END

END

Step 3 When flow reduces to normal, off-peak values, reinstall original speed limits.

The online algorithm can be stated as (for more details, we refer to Section 4.3 of the project report):

Online Algorithm Speed Harmonization

Input

- (\bar{u}_s, q) -curves for each of the n road segments. Note that we can extract the maximum capacities $c_0(k)$, $k = 1, 2, \dots, n$ of the road segments from these curves.
- Current speed limits $s_0(k)$, $k = 1, 2, \dots, n$ of the road segments.
- The minimum intervention duration T_{min} , i.e. the minimum time interval in which the speed limit remains constant.

Output

A set of dynamically changing speed limits for each of the road segments.

INITIALIZATION $c(k) \leftarrow c_0(k)$, $s(k) \leftarrow s_0(k)$

FOR $k = n, n-1, \dots, 2$

IF $q(k) \approx c_0(k)$

FOR all road segments $r = k-1, k-2, \dots, 1$

DO select a speed $u(r)$ for segment r such that
 $q(r) < c(r+1)$ and $u(r) \leq s(r)$

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                                set  $c(r) \leftarrow q(r)$ ,  $s(r) \leftarrow u(r)$ 
                                END DO
                        END FOR
                END IF
                set  $c(r) \leftarrow c_0(r)$ 
END FOR

Display new speed limit vector  $s(r)$ 
Wait for  $T_{min}$  time units, set  $s(r) \leftarrow s_0(r)$  and repeat the algorithm.

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Recall from Section 5.1 of the project report that temporary shoulder use should always be utilized in conjunction with speed harmonization:

Online Control Temporary Shoulder Use

Step 1 Check if shoulder lane is free of objects. If the shoulder lane is free, go to Step 2, otherwise, repeat Step 1 after some time.

Step 2 Open shoulder lane for traffic.

Step 3 If the average flows on the lanes are less than a pre-specified value, then close the shoulder lane.

After the execution of the above algorithms, local performance can be evaluated (see below). Furthermore, based on the above results one can adjust model parameters in the mesoscopic simulation model (see Chapter 3 of the project report) to obtain the network impacts, if any. For instance, one can enlarge road capacities in the mesoscopic model to represent the increase in capacity when shoulder lanes are opened for traffic.

Travel Time

One of the performance measures is travel time (saving). One can focus on the travel time between specific origin-destination pairs or the network-wide travel time (global). Moreover, one can also purely examine the change in travel time on the corridor itself (local). Next we briefly indicate how the travel time savings can be measured.

Local: Run microsimulation to evaluate the total travel time before and after speed harmonization and peak-period shoulder use are applied. The travel time savings can now be computed for the (microscopic) network as a whole, or for the (average) individual traveler on the corridor under consideration.

Global: Run a mesoscopic simulation of the entire network and evaluate the total travel time. Adjust parameters (e.g. road capacities) in the network-level model to reflect the changes due to the advanced traffic management strategies (see Chapter 3 of the project report) and evaluate the new total travel time. The difference amounts to the saving in system travel time. By restricting our attention to specific origin-destination pairs, the travel time saving per origin-destination pair can be obtained.

Travel Time Reliability

Travel time reliability is a crucial element in the route choice process. Hence it is natural to consider it as a measure of performance. To evaluate this measure, we perform local and global simulations.

Local: Run microsimulation as above (i.e. under the heading “Travel Time”). Instead of evaluating some average total travel time, now the variability of the travel time should be evaluated. This can be accomplished by the calculation of the sample variance of the travel time before and after the implementation of the traffic management strategies. Of course, to evaluate the sample variance, multiple runs of the microscopic model are needed. Depending on the software, this calculation is typically done manually, instead of being standard simulation output.

Global: Same as above. However, now, we use the travel time data obtained from the mesoscopic simulation model to estimate the variance of travel time. Again, this step is typically performed manually.

Safety

Safety is an important consideration in transportation systems. Unlike the above measures, safety is typically a local performance measure. One should not expect to find measurable changes in safety at the network level. To measure safety, we suggest a logistic regression approach (see Chapter 6 of the project report).

Ideally, a crash potential function $p(x)$ is estimated based on the specific corridor’s crash history. The evaluation of safety then simply reduces to the real-time evaluation of $p(x)$ as a function so the real-time prevailing traffic conditions x . Traffic data obtained from loop detectors around the incident time are used to develop the crash potential function. These data are average of speed, volume, and occupancy, and standard deviation of speed, volume, and occupancy.

Emissions and Vehicle Fuel Consumption

Emissions and vehicle fuel consumption is an important environmental measure to be considered. Conveniently, these data are standard output in virtually all simulation packages. There are also software analysis programs such as MOBILE and MOVES developed by the Environmental Protection Agency (EPA); these can be used to supplement simulation outputs and are available to download for free on the EPA’s website. Key inputs for MOBILE and MOVES can be obtained from the simulation outputs discussed above.

Local: Run microsimulation “before and after” and compare the differences in emissions/vehicle fuel consumption. As noted above, outputs from the simulation can also be input into MOBILE or MOVES to obtain results regarding emissions and fuel consumption.

Global: Run mesoscopic simulation “before and after” and compare the differences in emissions/vehicle fuel consumption. As noted above, outputs from the simulation can also be input into MOBILE or MOVES to obtain results regarding emissions and fuel consumption.

IDENTIFYING INFRASTRUCTURE IMPROVEMENTS

The following sections discuss what is recommended or what has been used in the past for each infrastructure element necessary to deploy speed harmonization and peak period shoulder use. Each of these topics has been covered in additional detail in different chapters of the project report. A synopsis is provided below for ease of reference and to help guide the review of each candidate site; essentially, the analyst or engineer will compare the existing features of the candidate site to the desired features. The more the existing features match or coincide with the desired features the more attractive the site becomes based on the infrastructure present. Ultimately, the information below can be used to identify the necessary capital and operational/maintenance costs necessary for the site to be successful.

Intelligent Transportation Systems (ITS)

As discussed in Chapter 7 of the project report, ITS is critical for providing accurate information to motorists, collecting information regarding the traffic flow, and enforcing the traffic operation controls in place. In deploying speed harmonization, ITS provides the information necessary to set the appropriate speed limit given the traffic conditions, to communicate that speed limit to motorists and to consistently enforce the speed limit. Similarly, when deploying peak period shoulder use, ITS provides information on when it is best to open and/or close the shoulder to traffic, to communicate whether or not the shoulder is open to motorists, and to consistently enforce the appropriate use of the shoulder.

ITS technologies previously used in speed harmonization and peak period shoulder use can be summarized into three categories of traffic surveillance, information dissemination, and enforcement. Table 2 summarizes the recommendations made in Chapters 7 and 8 of the project report regarding each of these functions.

Table 2. ITS Infrastructure Recommendations

ITS Function	Recommendation
Traffic Surveillance	Place camera detectors at 1-mile intervals to detect incidents on the main line and shoulders. Place loop detectors at 1500 to 2000 foot intervals to gather data regarding traffic flow characteristics.
Information Dissemination	Place variable message signs at 1-mile intervals preferably on overhead gantries.
Enforcement	Place photo radar sensors and cameras at approximately 1-mile intervals. Take care to enable the system to provide motorists with ample time to respond to changes in the posted speed limit before enforcing it.

Chapters 7 and 8 of the project report contain additional details.

Horizontal and Vertical Roadway Alignment

As noted in Section 5.3 of the project report, the roadway geometry is most critical for peak period shoulder use; the deployment of peak period shoulder use changes the operational cross-

section of the highway or freeway by adding the equivalent of one or two lanes of traffic. The geometric design guidelines focus on providing an overview of the primary horizontal and vertical alignment considerations applicable to deploying peak period shoulder use. The guidelines were developed in consultation with the TxDOT Roadway Design Manual, AASHTO's Policy on Geometric Design, and AASHTO's Roadside Design Guide. A key assumption made while developing these guidelines is that the shoulder will be used as a travel lane under conditions in which the freeway operating speed is 35 mph or less.

Table 3 summarizes the basic geometric design guidelines and considerations for using the shoulders as travel lanes.

Table 3. Roadway Geometric Design Guidelines and Considerations

Geometric Characteristics/Considerations	Guidance
Shoulder Lane Width	10 feet with low to no heavy vehicles in shoulder lane. 11 feet to allow for more extensive use of shoulder lane by heavy vehicles.
Acting Shoulder Width	2 feet to 4 feet to provide shy distance and lateral support to pavement.
Pavement	Structural composition consistent with mainline. Cross slope 2.5% or less; maintain driver comfort, control and ample drainage.
Horizontal Curves	Verify that superelevation and width are adequate/appropriate for vehicle use.
Vertical Clearance	Verify 16.5 feet of vertical clearance across shoulder lanes; mitigate discrepancies as specified in TxDOT Roadway Design Manual.
Horizontal Clearance	Verify appropriate horizontal clearance of 30 feet for mainline travel and 16 feet for freeway ramps. Mitigate discrepancies via appropriate treatments identified in the TxDOT Roadway Design Manual and/or AASHTO's Roadside Design Guide.
Transition Areas (Closed to Open Shoulder and vice versa)	Open shoulder at a 10 to 1 taper (one lateral foot for every 10 feet traveled). Close shoulder at a 50 to 1 taper (one lateral foot for every 50 feet traveled).
Entrance/Exit Ramps	Implement yield control for traffic entering freeway on an auxiliary lane (see Section 5.3 of the project report for details).
Incident Management	Provide emergency vehicle access via a case-by-case review of each site. Options include managing lanes via lane assignment controls, providing median breaks, and/or recoverable areas adjacent to freeway. Provide vehicle refuge areas every 1/3 rd of a mile; areas of 15 feet in width and 150 feet in length.
Freeway Operations in Dark	Verify traffic control devices in use meet night-time visibility standards outlined in MUTCD.

As is noted in Chapter 5 of the project report, each candidate site is likely to present unique and challenging characteristics, solutions to which may require variations from the guidance

summarized in Table 3 and/or presented in Chapter 5. In such situations, engineers should use their best judgment as to the appropriate mitigations. Additional details regarding these design guidelines can be found in Chapter 5.

DEVELOP ENFORCEMENT AND EDUCATION PLANS

Enforcement and education are two key components to successfully implementing new traffic operation schemes. Enforcement is necessary to ensure motorists comply with the posted regulations and education is critical to ensure motorists understand what is expected of them on the roadway. Each of these components is discussed in more detail below.

Enforcement Considerations

Chapter 7 of the project report discusses enforcement considerations in particular detail. There are two basic types of enforcement: one is manual and the other is automated. Automated speed enforcement tends to be less common in the United States than abroad, particularly compared to European countries. Despite its scarce use in the United States, its proven effectiveness makes it a priority recommendation for successfully implementing speed harmonization and peak period shoulder use. Chapter 7 discusses some of the obstacles facing automated speed enforcement in the United States as well as recommendations in developing the legal framework necessary to use automated enforcement techniques in the United States. Listed below are the key elements of variable speed limit legislation recommended by Hines and McDaniel (2002) in their National Highway Cooperative Research Project (NCHRP) publication entitled *Judicial Enforcement of Variable Speed Limits*:

1. The statutory purpose should allow a change in speed limit to protect public safety and permit the legislature to delegate to an agency the power to prescribe details after they have fixed a primary policy or standard.
2. The law should require the change in the speed limit to be based on engineering and traffic investigations; in the context of variable speed limits, these would show the need for and the benefit of variable speed limits under certain situations.
3. The statute must require posting for the new limit to be effective.
4. The statute must require posting of advance warning that the legal speed limit is changed ahead.
5. The law must require that any information or charging documents include the existing speed limit and speed at which it is alleged the charged driver's vehicle was traveling.
6. The law might prohibit automatic enforcement within a certain distance of the new limit to allow reasonable time for drivers to adjust their speeds.
7. The law should provide broad discretion to administrative agency for enactment of regulations and sub-delegation of decision-making power.
8. Either laws or regulations should provide for certain evidence by affidavit. This means where the speed limit is decreased due to temporary hazards (e.g., traffic, weather) evidence of the reasons and the specific speed limit on the highway where the violation allegedly occurred must be presented.

For additional details and information, please refer to Chapter 7 of the project report.

Education Considerations

Public education for new operating strategies and traffic control devices can be useful in proactively informing the public of what is expected of them under certain conditions. Deploying speed harmonization and peak period shoulder is likely to result in modifying the character and appearance of the roadway as well as implementing new signs or traffic control devices intended to convey critical information to motorists. In addition to traditional public outreach meetings, simple informational flyers included in utility bills, short T.V. commercials, public announcements via radio, and informational flyers made available for pick up at grocery stores, schools, and libraries are useful forms of communication. These forms of communication can make it easier for motorists to understand the purpose for the changes, what is expected of them, and the benefits intended to come out of the new traffic control strategies.

APPLY COST BENEFIT ANALYSIS FRAMEWORK

The basic approach to conducting CBA is to quantify the potential changes in performance measures (i.e., potential benefits) under a “do-nothing” scenario and an alternative “build” or implementation scenario. The difference in performance is converted to a monetary value and compared to the cost of the proposed alternative. The potential benefits (or disbenefits) associated with implementing speed harmonization and peak period shoulder use were quantified during the “Construct and Run Simulation Analysis” step discussed above. The potential costs associated with deployment were also identified above in the “Identify Infrastructure Improvements” step. Within the CBA framework, these elements are converted to monetary values and compared.

As discussed in Chapter 8 of the project report, the method for comparing the benefits and costs can be a net present value analysis, benefit cost ratio, cost-effectiveness evaluation, or another similar method. The comparison will indicate whether or not the proposed alternative is economically valid (i.e., whether or not the monetary benefits are anticipated to sufficiently outweigh the costs). A framework for conducting such analysis as related to speed harmonization and peak period shoulder use is presented below.

- 1) Identify candidate sites for evaluation.
- 2) Conduct preliminary analyses for “do-nothing” and implementation scenarios per site (achieved when constructing and running simulation discussed above).
- 3) Identify design life to be considered in CBA.
- 4) Identify discount rate (minimum rate of return) to use for CBA.
- 5) Identify CBA comparison methodology or methodologies (e.g., NPV, B/C ratio).
- 6) Identify benefits to quantify (i.e., identify the performance measures to be considered).
- 7) Conduct more focused analyses for “do-nothing” and implementation scenarios per site to quantify annual potential benefits over the course of the design life.
- 8) Use outputs for “do-nothing” and implementation scenarios per site to quantify difference in performance per year of design life.

- 9) Convert anticipated difference in performance per year to monetary values per year of the design life and convert annual monetary benefits to a total present value.
- 10) Estimate difference in costs for “do-nothing” and implementation scenario per year of design life and convert annual costs to a total present value.
- 11) Compare present value monetary benefits and costs via chosen methodology.

This framework can be modified to fit within the standard TxDOT CBA procedures. The critical considerations with regards to speed harmonization and peak period shoulder use are quantifying the related benefits and costs. Please refer to Chapter 8 of the project report for guidance on converting the performance measures (e.g., travel time, travel time reliability, emissions, safety) to monetary values.

CONSIDER QUALITATIVE IMPACTS

Thus far feasibility and deployment considerations have been focused on quantifiable benefits and costs; however not all potential impacts can be quantified, but are still worth considering qualitatively. Many of these measures are complex and are related to societal considerations not immediately conducive to representing with a numerical value (e.g., community cohesion). There are a few measures, such as noise that can be quantified with more detailed analysis; however, this detailed analysis may be beyond the scope of many feasibility assessments. To be able to capture these measures in some form during the feasibility, screening and deployment process, the analyst can qualitatively assess them.

Table 4 summarizes potential qualitative measures for consideration.

Table 4. Potential Qualitative Characteristics

Measure	Description
Noise	Anticipated change in noise pollution due to change in traffic volume and/or mix to traffic.
Accessibility	Ability to access basic services (e.g., schools), employers, quality of life destinations (e.g., shopping), and local access (e.g., sidewalks).
Community Cohesion	The degree to which existing neighborhoods, communities, and recreational areas remain intact. Considers residents and local businesses necessary to relocate and/or residents and local businesses isolated from the community.
Equity	Distributive effect of the proposed project; what is the investment’s impact across societal groups?
Environmental Considerations	Impacts on water resources, wetlands, habitats of endangered/threatened species, and other similar considerations.
Regional Development/Economic Effects	Assessment of whether proposed project would attract new development or employers to the region.
Aesthetics	Visual impact of proposed project compared to “do-nothing” scenario.

The measures listed above are not exhaustive nor will they be applicable for all candidate sites. Table 4 is provided as a reference to help guide the conscious and consistent consideration of welfare measures not conducive to quantifying numerically.

In addition to considering the qualitative measures noted above, holding public meetings to gather thoughts from the community and gage community support is likely to be particularly useful in identifying candidate sites most conducive to speed harmonization and peak period shoulder use. As with many transportation initiatives, gaining community support can be a powerful catalyst in implementing new traffic control strategies.

SUMMARY

The collective purpose and goal of this handbook is to present guidance for conducting analyses for assessing the feasibility of speed harmonization and peak period shoulder use at candidate sites. The analysis approach presented incorporates the cost benefit analysis framework and the operational deployment strategy (presented in Chapter 8 of the project report) previously developed for this research project. This handbook draws upon information provided in different chapters of the project report. The project report can be referred to for additional details, as necessary.

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