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16. ABSTRACT

Technology awareness, use, and application are required to realistically and accurately model strategies (and their performance measures) that define success in corridor planning. Performance measures derived from each implementable strategy through a project that improves mobility, safety, reliability, sustainability, and equity are helpful to policy-makers in decision-making at various levels of planning. The primary goal of this research was to develop a spreadsheet-based corridor planning tool (CPT) in Microsoft Excel and train system planners and decision-makers on the developed tool through a webinar. Further, a literature review and data exploration were carried out to identify critical elements and inputs needed for the tool.

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Task 3879: Innovation Tools and Concept Strategies for System Planning

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California State University Long Beach

Final Report

June 29, 2023

Contents

1. Introduction

In recent times, transportation has witnessed an increase in the volumes of data and their sources, powerful computational platforms, and increasingly capable visualization and analytical tools ([1]) – which has enabled transportation agencies in the effective management of transportation systems and corridors. However, these developments have also added the complexity of corridor monitoring and management due to different levels of mode users using the system and seeking satisfaction from its use. Technology awareness, use, and application are required to realistically and accurately model strategies (and their performance measures) that define success in corridor planning. Performance measures derived from each implementable strategy through a project that improves mobility, safety, reliability, sustainability, and equity are helpful to policy-makers in decision-making at various levels of planning.

2. Objective

The primary goal of this research was to develop a spreadsheet-based corridor planning tool (CPT) in Microsoft Excel and train system planners and decision-makers on the developed tool through a webinar. Further, a literature review and data exploration were carried out to identify critical elements and inputs needed for the tool.

3. Literature Review

The literature review was carried out by accessing publications through online web searches and other useful resources provided by Caltrans. The researchers gathered various reports, tools, journals and conference papers on corridor planning. The most widely used online literature search database on transportation, TRID (https://trid.trb.org/), was used for this purpose, besides using Google Scholar and Google search. Individual State departments of transportation (State DOTs) websites were used to collect pertinent information on corridor planning strategies.

3.1. Defining strategies

For the various available traditional and innovative strategies in transportation planning, guidance is needed to evaluate each strategy and define them for corridor planning impacts. Therefore, a few key but critical questions need to be answered to identify those strategies that will make mobility along the corridor efficient adhering to sustainability, equity, reliability, and safety. Some of these critical questions are ([2]):

- How well would these strategies address the goals established for the corridor?
- What other impacts would they have – both positive and negative?
- If resources are limited, which strategies should be undertaken first?

[1] FHWA, "Scoping and Conducting Data-Driven 21st Century Transportation System Analyses", FHWA-HOP-16-072, January 2017.

[2] Vermont Corridor Management Handbook 2005

The answers to the above three questions helped shape the spreadsheet tool development. For example, the likely impacts of quantitative methods for strategy evaluation can help stakeholders choose alternative strategies to achieve the desired goal(s) for a corridor. Subsequently, an analysis could be carried out to understand the outcome of a strategy (with or without it). For example, a FHWA report on I-15 corridor in San Diego showed that with integrated corridor management, all agencies were informed about incidents within 5 minutes of an incident occurring, compared to without it, which took almost 30 to 60 minutes to know about an incident on the corridor ([3]).

The three most common timeframe classifications used in practice for corridor planning (and, in fact, for most transportation projects) are:

1. Short-term- (less than five years),
2. Medium-term - (five to 10 years), or
3. Long-term - (more than 10 years)

The above timeframe categories depend upon considerations such as:

- Priority level of the strategy and its implementation
- Timeframe over which need is likely to occur
- Expected availability of funding
- Length of study process required to design and implement the strategy
- Coordination with other relevant processes (e.g., local comprehensive plan updates, statewide transportation planning process), and
- Other considerations, such as expected time required to gather adequate support for the project.

In addition, the tool developed for corridor planning must consider the possibilities of short-term (compared to long-term) strategies becoming high-priority strategies.

3.2. Enumerating strategies

The literature review showed that most States follow similar strategies used in corridor planning with performance measures used to assess the success of those strategies. However, it has also been found that while most States have some guidance on corridor planning, several overlapping performance measures exist for each strategy's assessment.

The Vermont Corridor Management Handbook 2005 ([4]) provides clear guidance on elements that define a corridor, strategies recommended, and their effective evaluations that were found useful for translation into a spreadsheet tool.

A corridor includes the following in its definition - a stretch of roadway, its right-of-way (including utilities, drainage, traffic control devices, and parallel sidewalks or pathways), adjacent land use

[3] FHWA Report, "Analysis, Modeling, and Simulation for the Interstate 15 Corridor in San Diego, California – Post-Deployment Analysis Plan", FHWA-JPO-16-393, 2016.
[4] Vermont Corridor Management Handbook 2005.

development, and elements that compose the scenic view. The corridor can also appropriately include one or more parallel roadways and/or rail lines.

Corridor management studies typically have a long-term focus (addressing land-use and strategies) and span over a 20-year or more. Literature reviews show that several strategies may be included as part of the corridor planning and management practice and have also been identified as goals of the California Transportation Plan (CTP) 2050 (as noted below), along with their applicability to specific corridor types. The strategies are ([5] ,[6]):

i. Land use strategies such as zoning, land conservation, or access management (all corridor types[7])
ii. Mechanisms for inter-jurisdictional cooperation (all corridor types)
iii. Corridor's multimodal and smart-growth approach with improved accessibility to travel options (all corridor types)
iv. Available informational tools to make smart travel choices within the corridor (all corridor types)
v. Expand access to safe and convenient active transportation options (all corridor types)
vi. Improve transit, rail, and shared mobility options (freeway-highway, transit, complete streets)
vii. Advance transportation equity (freeway-highway, transit, complete streets)
viii. Enhance transportation system resiliency (all corridor types)
ix. Enhance transportation safety and security (all corridor types)
x. Improve goods movement systems and infrastructure (freight)
xi. Advance zero-emissions vehicle (ZEV) technology and supportive infrastructure (freeway-highway, freight, transit)
xii. Manage the adoption of connected and autonomous vehicles (all corridor types)
xiii. Price roadways to improve the efficiency of auto travel (freeway-highway)
xiv. Encourage efficient land use (all corridor types)
xv. Expand protection of natural resources and ecosystems (all corridor types)
xvi. Strategically invest in state of good repair improvements (all corridor types)

The CTP 2050 also illustrates how each recommendation (as a strategy) could fulfill its vision across safety, climate, equity, accessibility, quality of life & public health, environment, economy, and infrastructure goals (see image below in Fig. 1).

[5] California Transportation Plan 2050, February 2021.
[6] FHWA Report, "Analysis, Modeling, and Simulation for the Interstate 15 Corridor in San Diego, California – Post-Deployment Analysis Plan", FHWA-JPO-16-393, 2016.
[7] All four corridor types are freeway-highway, transit, freight, and complete streets.

RECOMMENDATIONS:

Recommendation	Safety	Climate	Equity	Accessibility	Quality of Life & Public Health	Environment	Economy	Infrastructure
1 Expand access to safe and convenient active transportation options	✓	✓	✓	✓	✓	✓	✓	✓
2 Improve transit, rail, and shared mobility options		✓	✓	✓	✓	✓	✓	✓
3 Expand access to jobs, goods, services, and education	✓	✓	✓		✓	✓		
4 Advance transportation equity			✓	✓	✓		✓	
5 Enhance transportation system resiliency	✓	✓	✓	✓	✓	✓	✓	✓
6 Enhance transportation safety and security	✓		✓	✓	✓			✓
7 Improve goods movement systems and infrastructure		✓	✓	✓		✓	✓	✓
8 Advance Zero-Emissions Vehicle (ZEV) technology and supportive infrastructure		✓	✓			✓		✓
9 Manage the adoption of connected and autonomous vehicles	✓		✓	✓				✓
10 Price roadways to improve the efficiency of auto travel		✓	✓	✓	✓	✓	✓	✓
11 Encourage efficient land use		✓	✓	✓		✓		✓
12 Expand protection of natural resources and ecosystems		✓	✓		✓	✓		
13 Strategically invest in state of good repair improvements	✓		✓	✓				✓
14 Seek sustainable, long-term transportation funding mechanisms	✓	✓	✓	✓	✓	✓	✓	✓

Figure 1: California Transportation Plan 2050 recommendations (Source: CTP 2050 document)

Other innovative strategies addressing sustainability goals are from States like Arizona, which is focusing on electric vehicle (EV) charging corridors, e.g., Arizona's I-10 alternative fuels corridor deployment plan that adheres to the FHWA's current criteria as follows ([8]):

- Availability of public Direct Current Fast Charge (DCFC) stations
- No greater than a 50-mile distance between one station and the next on the corridor
- Charging or fueling stations no greater than five mile distance off the highway
- Specific Combined Charging System (CCS) connectors required at each DCFC

In addition, the literature review showed several efforts from the FHWA, State DOTs, and other private entities focusing on strategies for Connected and Automated Vehicle (CAV) corridors with the use of Intelligent Transportation Systems (ITS), especially for freight and transit ([9]).

[8] FHWA, "Arizona Interstate 10 Alternative Fuels Corridor Deployment Plan for Electric Vehicle Charging and Compressed Natural Gas Fueling", Pima Association of Governments and Arizona Department of Transportation, November 2020.

[9] Automated Vehicle Activities and Resources, accessed on June 20, 2022, https://highways.dot.gov/automation

Recently, strategies to accommodate wildlife movement (as another mode under environment and ecology context) across a corridor have also been recognized for consideration in planning ([10]).

3.3. Prioritizing strategies

Available guidance on analyzing strategies shows that it is helpful to assign a certain level of recommendation to each strategy, such as “high,” “medium,” “low,” or “not recommended,” based on considerations such as:

- The magnitude of the problem/need to be addressed (major, moderate, minor)
- Certainty of need (existing/immediate, forecast and likely to occur forecast but speculative)
- Cost-effectiveness of proposed solutions (high, medium, low)
- Level of support for strategy (widespread, mixed, weak)
- The potential availability of adequate funding (likely, uncertain, unlikely), and
- Negative impacts associated with strategy (minimal/none, moderate, high).

Strategies that are rated as “not recommended” can be based on the following three reasons:

i. If they do not effectively or cost-effectively address corridor needs,
ii. Are inconsistent with the corridor vision or other policies; or
iii. If funding or other supporting actions are unlikely to be achieved in any reasonable timeframe.

3.4. Evaluating strategies

Among various references and guiding documents that were reviewed, the Vermont Corridor Management Handbook guides tools and methods for corridor planning, highlighting their applicability, advantages, and disadvantages through application examples. However, the handbook also cautions against increasing tool sophistication resulting in increased data requirements, assumptions, and skills to use the tool. The handbook also states that qualitative evaluation will suffice for many types of strategies and can provide a valuable supplement to quantitative analysis. Further, talking about the results of the strategy analysis, the handbook outlines various formats that can be used, such as the following:

- A text description of findings (both quantitative and qualitative) of how each strategy performs on each of the evaluation criteria
- Tables or matrices summarizing quantitative findings (e.g., travel time savings, crash reductions); and,
- Graphics conveying impacts in visual terms (e.g., maps showing the degree of congestion by road segment/intersection, build-out development locations).

[10] Report - “Practitioner’s Guide to Movement and Place - Implementing Movement and Place in NSW”, NSW, March 2020.

Specific techniques, such as multi-criteria decision-making (MCDM), can be deployed to identify one or more critical strategies by stakeholders ([11]).

As shown below, results with summarized findings in an evaluation matrix are suggested for clarity and decision-making – example shown in the image of Fig. 2. The columns of the impact matrix correspond to each strategy or strategy package, while the rows correspond to each evaluation criterion or performance measure. Further, a symbol shows how strongly (positively or negatively) each strategy rates on a specific criterion. The matrix can be probed for design (or development) within a spreadsheet tool for the measures evaluated for a strategy.

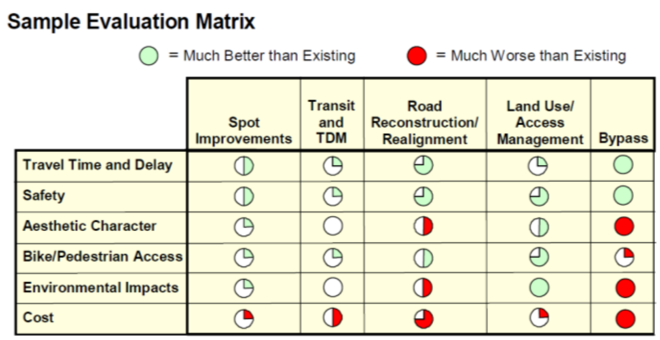

Figure 2: Sample evaluation matrix (Source: Vermont Corridor Management Handbook, 2005)

[11] Mardani, A., Zavadskas, E. K., Khalifah, Z., Jusoh, A., & Nor, K. M. (2016). Multiple criteria decision-making techniques in transportation systems: A systematic review of the state of the art literature. Transport, 31(3), 359-385.

3.5. Performance measures and metrics

Performance measures often differ for each corridor type because of the transportation mode involved. Still, there appears to be an overlap of measures among various corridor types, such as improvement in travel time, safety, accessibility etc. Literature review showed that various performance measures (and metrics) could be used to evaluate the performance of four specific corridor-types: freeway/highway, freight, transit and complete streets. These corridor types have been identified as a focus for corridor planning effort ([12]). A summary of these performance measures has been presented in Appendix B-E.

3.6. Potential data sources from California for performance metrics

Some of the potential data sources that can contribute to the tool input for calculating performance measures are documented below for each of the four specific corridor-types.

1. Freeway-Highway Corridor Assessment
   Data sources:
   i. Performance Measurement System (PeMS)
   ii. Traffic Accident Surveillance and Analysis System
   iii. Highway Performance Management System
   iv. Pavement Condition Index

2. Transit Corridor Assessment
   Data sources:
   i. Transit Operator data
   ii. Caltrans
   iii. Local Govt.

3. Corridor-Based Freight Assessment
   Data sources:
   i. PeMS
   ii. Caltrans, HPMS, field collection, big data sources
   iii. Port / Intermodal facility operator

4. Complete Streets Corridor Assessment
   Data sources:
   i. Geospatial data inventory
   ii. Travel demand model
   iii. Land use maps
   iv. SWITRS/TASAS
   v. Transit Operator data
   vi. Google Maps/Streetview

[12] Corridor Planning Process Guide, Division of Transportation Planning, https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/system-planning/systemplanning/corridor-planning-process-guide-12-24-2019-a11y.pdf

The Caltrans Corridor Planning Process Guide has also recommended other data sources relevant to California:

- Regional Transportation Plans and General Plans
- Bike Master Plans, Local Transit Agency Plans
- Congestion Management Plans
- Prior corridor studies and planned and programmed projects from existing plans, studies, and reports
- Proposed project CEQA/National Environmental Protection Act (NEPA) environmental documents
- For current and forecasted population and employment, the US Census Bureau, California Department of Finance forecasts, and local sources (such as chambers of commerce)
- Caltrans system information, sources include the Division of Research, Innovation, and System Information, Division of Operations, and Division of Transportation Planning, and Caltrans Performance Measurement System (PeMS) data
- Caltrans Geographical Information System (GIS) Data Library, and local sources such as MPOs and RTPAs.

3.7. Review Summary

Some highly cited works of researchers provide guidance and recommendations on best practices for corridor planning, especially in the context of multimodal planning ([13]). These recommendations complement strategies that various transportation agencies adopt for a corridor's development.

A review of various tools deemed relevant for corridor planning indicated that complexities might occur in evaluating performance measures (and their corresponding metrics) if multimodal transportation is considered within the same corridor type (freeway/highway, transit, freight, and complete streets).

In addition, several performance measures for the same corridor type exist and are recommended based on data available from various sources. However, having all of the measures in a spreadsheet-based tool for a corridor planning was not be practical to keep the tool simple, fast, and easy to use. These review findings are significant as we embarked on data exploration research in our next task of this project.

Thus, to achieve the tool's primary purpose in corridor planning and with numerous available measures and metrics, the six key analysis points recommended by the Caltrans Corridor Planning Process Guide served as a guidance:

1. Geographic Scope
2. Facility Type
3. Travel Mode
4. Improvement Strategy
5. Traveler Response and Response Timeframe, and

[13] Litman, T. (2021). Introduction to multi-modal transportation planning. Canada: Victoria Transport Policy Institute.

6. Performance Measure

The above six analyses were carried out within the output module of the tool as presented in the proposed framework of Fig. 3 shown below.

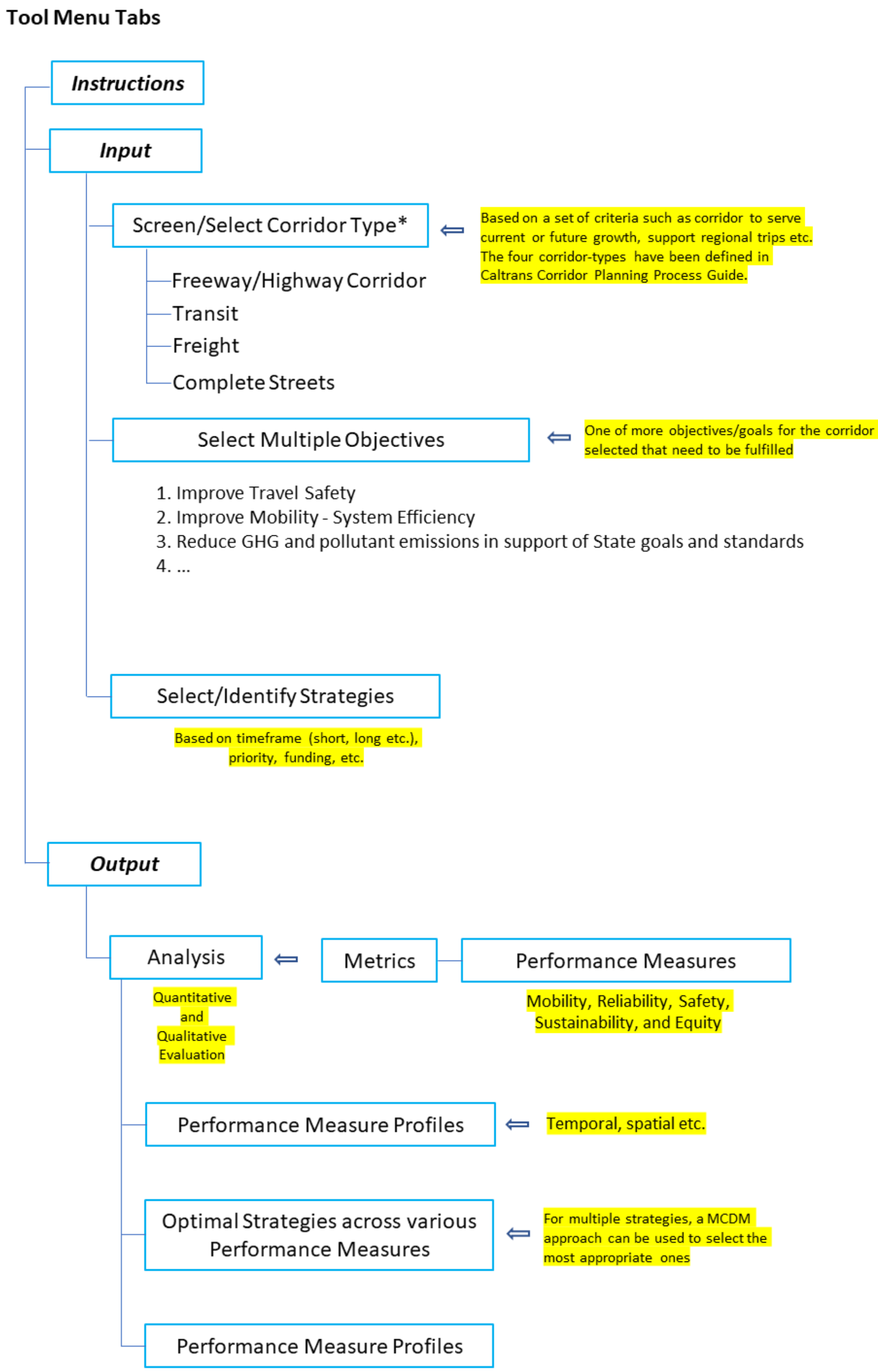

Figure 3: Tool framework with measures and metrics as input

4. Data Exploration

Corridor planning involves evaluating safety, mobility, reliability, sustainability and equity measures. An important input for such an evaluation in a spreadsheet-based corridor plan tool is the data on these various performance measures. However, obtaining the appropriate data for the tool to achieve the corridor planning goals becomes a challenge due to the non-availability of data. This document provides an overview of what data are available and if there are any barriers to accessing them for the spreadsheet tool to evaluate performance measures.

4.1. Data Needs and Justification

This section describes the information needed on data and purpose/justification to enhance tools for corridor planning. The information has been compiled per the four specific corridor-type mentioned in the Caltrans Corridor Planning Process Guide ([14]) – transit, freeway-highway, freight and complete streets corridors. A summary of the data needed for each of the four corridor types has been compiled below.

4.1.1. Transit Corridor and Key Metrics

4.1.1.1. Ridership by route, line, or service

Ridership determines the overall passenger usage.

4.1.1.2. Service on-time percentage by route, line, or service

Necessary for sustained passenger ridership and usage.

4.1.1.3. Route, line, or service schedules

Information on schedules reflects the level of convenience and reliability for riders.

4.1.1.4. Infrastructure inventory and description

Number and type of transit-supportive infrastructure in the corridor

[14] Caltrans Corridor Planning Process Guide, accessed on August 2, 2022. https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/system-planning/systemplanning/corridor-planning-process-guide-12-24-2019-a11y.pdf

4.1.2. Freeway-Highway Corridor and Key Metrics

4.1.2.1. Functional Classification

Functional class of different roadways determines design standards that must be applied for highways in corridor planning.

4.1.2.2. Volume

The objective is to assess bottleneck location, delay, speed, and productivity. Level-of-service (LOS) is calculated based on AADT. The LOS is required for specific intersections and analyzing usage patterns for roadway segments.

4.1.2.3. Level of Service (LOS)

Qualitative representation of the operational level of an intersection or arterial segment using letter grade ranging from A to F.

4.1.2.4. Speeds/Travel time

Congestion locations are determined based on low speed/high travel times, delays and route reliability.

4.1.2.5. Incident/Accident reports

The type of mitigation measures needed is determined based on incidents, accidents and crash analysis for a location.

4.1.2.6. Pavement condition

Pavement conditions could indicate investment needs for infrastructure upgrades.

4.1.2.7. Journey-to-Work Analysis

Zone-to-zone travel times and volumes useful for determining congestion location and parking needs are assessed based on the journey-to-work analysis.

4.1.3. Freight Corridor and Key Metrics

4.1.3.1. Lane Miles and Volume/ Capacity

The information reflects the overall performance of the corridor

4.1.3.2. Truck Volume

Indicator of corridor or route popularity

4.1.3.3. Truck Travel Time

Travel times are frequently used to indicate reliability

4.1.3.4. Number of containers transferred (truck or rail)

Measures the throughput and identifies potential bottlenecks in a corridor.

4.1.3.5. Tonnage/Goods Movement

Strategies that maximize goods movement require tonnage data for the corridor.

4.1.4. Complete Streets Corridor and Key Metrics

4.1.4.1. Pedestrian crossings, sidewalk continuity and gaps, shoulder widths, streetlights etc.

Pedestrian asset inventory provides information on the number and type of complete streets features within the corridor

4.1.4.2. Bicycle facility, continuity and gaps

Bike asset inventory provides information on the number and type of complete streets features within the corridor

4.1.4.3. Trip data and travel demand for active transportation-walking trips, bicycling trips, or short-distance automobile

Transportation travel demand along a corridor is determined based on trip data.

4.1.4.4. Trip generators

Locations of schools, parks, residential, etc., along with surrounding land-use information to a corridor, are necessary to estimate current and future demand for the corridor use

4.1.4.5. Roadway geometrics such as number of lanes, presence of crossings, etc., traffic data on volumes and speeds

Information on complete streets corridor infrastructure and mobility determines the active transportation level of traffic stress.

4.1.4.6. Collision Data/Systemic Safety Analysis

Crash mitigation strategies are effective with data input for active transportation safety analysis.

4.1.4.7. Transit routes, trips, stop access etc.

Current and future transit ridership/trips are estimated based on first-mile and last-mile transit access to stops.

4.2. Data Common to all Corridors

Data for the corridor planning tool can be identified and collected from appropriate sources. Some of these data apply to all four corridor types – freeway, transit, freight, and complete streets and have been compiled in the table 1 below:

Table 1: Common data across most corridor types

Land Use	**Description/Justification**
Existing and Future Land Use	Land use data is important to understand the context of transportation networks, growth centers, and jobs. Future land use data is required to understand the needs of the transportation system in a corridor study.
Cultural and Historic Resources	The impacts on cultural and historic resources must be identified and included in the corridor plans to understand any potential changes to the area's natural and built environments.
Natural Features	The impacted area defined in the corridor plan should account for any potential negative impacts on natural features and high-value resource lands.
Density/Form/Community Types	Population and housing density significantly impact the economic activities and mobility of those residing along the corridor. Form and building types near the corridor can help characterize the community types such as rural, suburban corridor, suburban center, suburban neighborhood, town center, village or urban neighborhood, or urban core.
Regulations and Studies	
Comprehensive or Master Plan and Other Studies	Any corridor study recommendations should draw insights from prior studies and address the existing comprehensive plan.

Long-Range Plan Characterization of Community Types	Community types and related policies for the corridor are necessary for guiding recommendations from the long-range plans.
Zoning and Subdivision and Land Development Ordinances	Regulations on land use, density, and bulk standards and municipal subdivision and land development ordinance for the design and layout of lots, streets and public utilities should be reviewed.
Transit-Oriented Development (TOD)	The corridor study plan should identify areas that are candidates for TOD – including suitable bus stop locations and rail stations.
Affordable and Workforce Housing and Mobility Needs	Corridor plans should include impacts on low- and moderate-income residents of the surrounding area. The findings will guide if affordable and workforce housing is needed near the corridor.
Green Building and Green Communities	Resource consumption can be optimized with green buildings and green communities that are healthy, safe, attractive, and walkable.
Demographics	
Existing and Forecasted Population and Employment	Population and employment forecasts can help determine demand and sustained use of the corridor for the future.
Major Employers	An inventory of major employers along a corridor may enhance the corridor analysis.
Equity and Opportunity	Equity and opportunity are important to understand the potential impacts of the corridor on disadvantaged populations.

4.3. Data Sources

Besides assessing data availability, the data sources and suitability of the data for the spreadsheet tool were also explored. These have been compiled in the tables 2-5 below for each corridor.

Table 2: Freeway-highway corridor assessment

Data Needs	**Data Source(s)**	**Data cleaning required for the spreadsheet tool application?** None, moderate or high?
Volume Speeds/Travel time	Performance Measurement System (PeMS), big data sources, Caltrans field collection	Moderate
Incident/Accident reports	Traffic Accident Surveillance and Analysis System, CA Highway Patrol, PeMS	High
Pavement condition	Highway Performance Management System, National Bridge Inventory Database, Caltrans State of Pavement Report, and/or Pavement Condition Index	High

Level of Service (LOS)	Caltrans' Maintenance division	None
Journey-to-Work Analysis	2010–2012 California Household Travel Survey, Longitudinal Employer-Household Dynamics (LEHD)	High

Table 3: Transit corridor assessment

Data Needs	**Data Source(s)**	**Data cleaning required for the spreadsheet tool application?** None, moderate or high?
Ridership by route, line, or service	Transit Operator data	Depends on the quality of data available or supplied
Service on-time percentage by route, line, or service		
Route, line, or service schedules		
Infrastructure inventory and description		

Table 4: Corridor-Based Freight Assessment

Data Needs	**Data Source(s)**	**Data cleaning required for the spreadsheet tool application?** None, moderate or high?
Lane Miles and Volume/ Capacity	PeMS	None
Truck Volume	Caltrans, Highway Performance Management System (HPMS), field collection, big data sources	None
Truck Travel Time	Caltrans, big data sources	None
Number of containers transferred (truck or rail)	Port / Intermodal facility operator	None
Tonnage/Goods Movement	Freight Analysis Framework (FAF)	Moderate

Table 5: Complete Streets Corridor Assessment

Data Needs	**Data Source(s)**	**Data cleaning required for the spreadsheet tool application?** None, moderate or high?
Pedestrian crossings, sidewalk continuity and		High

gaps, shoulder widths, streetlights etc.	Google Maps/Streetview, Postmile Query Tool, Geospatial data inventory	
Bicycle facility, continuity and gaps.		
Level of comfort and convenience	Caltrans and other local data sources	Moderate
Trip data and travel demand for active transportation-walking trips, bicycling trips, or short-distance automobile	Travel demand model, Big Data Platforms, Land use maps	High
Trip generators		
Roadway geometrics such as number of lanes, presence of crossings, etc., traffic data on volumes and speeds	Google Maps/Streetview, Local data, Caltrans GIS Data	High
Collision Data/Systemic Safety Analysis	Statewide Integrated Traffic Records System (SWITRS)/ Traffic Accident Surveillance and Analysis System (TASAS)	Moderate
Transit routes, trips, stop access, etc.	Transit Operator data, Geo-spatial walkable/bikeable catchment analysis.	Depends on the quality of data available or supplied

5. Tool Limitations

The spreadsheet-based tool was developed in Microsoft Excel and has a list of features that make it versatile, easy and simple to use. A number of metrics can be provided as input for evaluating the five measures – mobility, reliability, sustainability, safety and equity. The tool inputs include information on corridor type, land-use information, sensitivity analysis, and five strategies can be evaluated at once. The output obtained from the tool are the performance measure scores for each strategy analyzed, comparisons of strategies and the recommended optimal strategy.

However, the tool has some limitations, and these include the following:

- The tool provides guidance on strategy/project selection – does not provide insights to implementation challenges (feedback, closing the loop)
- The tool does not provide guidance on measuring 'efficient' land use (measures included limited to mobility, reliability, safety, sustainability and equity), and
- The tool's output includes the recommended strategy that does not feed into transportation funding programs and other local or regional planning process. The cost of strategy implementation can depend on the available funds.

To overcome the tool limitations, Phase II framework for the tool is proposed that would align with best practices of strategy evaluations.

6. Phase II Framework

The tool Phase I framework essentially involved inputs and outputs with set of screening criteria and is presented below:

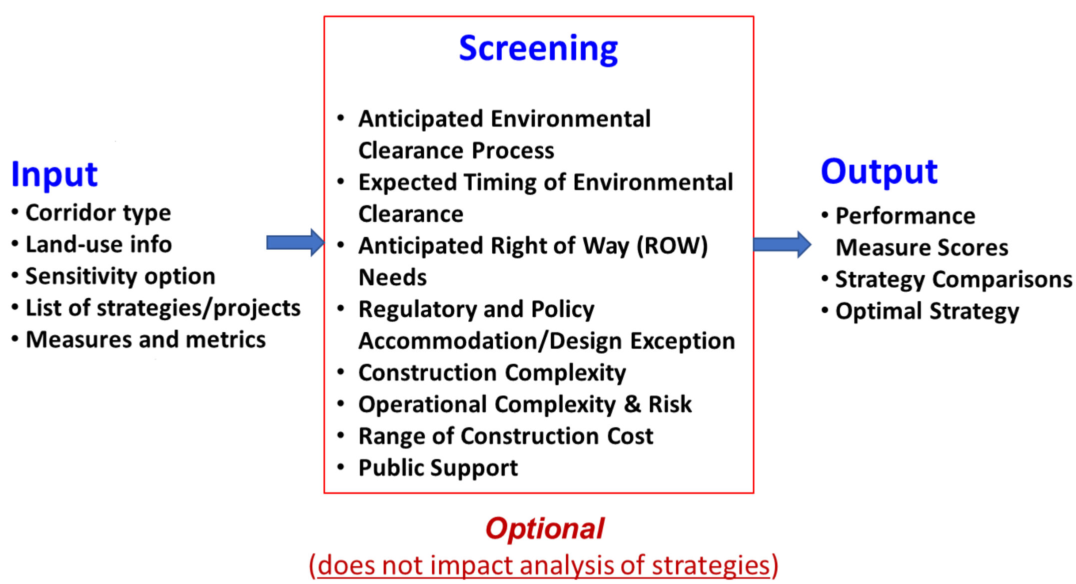

Figure 3: A brief summary of Phase I framework

The screening criteria used in Phase I were optional and do not impact the strategies selected for evaluation. Under Phase II framework, the screening criteria will be the mandatory checks on feasibility of a strategy before it is evaluated. This will provide the opportunity to the tool users to re-consider a strategy for evaluation through a feedback mechanism that ensures only selected final strategies or projects, satisfying all screening criteria, are evaluated for further consideration.

Thus, Phase II framework for the tool will be much more robust and appropriate for applications in corridor planning. The modified framework for Phase II would look like the one shown in Fig. 4 below:

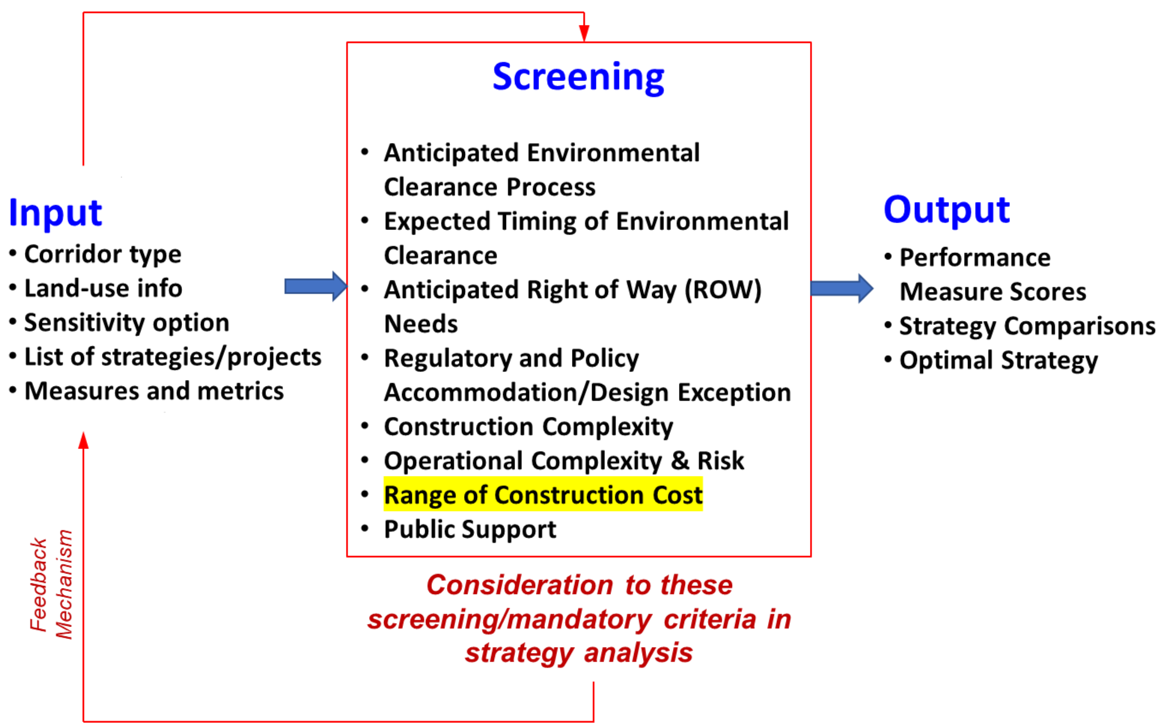

Figure 4: Modified input-output for proposed Phase II framework for corridor planning tool

APPENDIX

A. Example tools for corridor planning

A.1. SEMCOG/MDOT Multimodal Tool

The Southeast Michigan Council of Governments (SEMCOG)[15] Multimodal Tool has two modules: Modal Prioritization Tool and the Right-of-Way Allocation tool. The Modal Prioritization Tool identifies a project corridor, reviews modal priorities, and determines land use contexts through a webmap[16]. The Right-of-Way Allocation tool (in Excel) evaluates existing or proposed cross-sections of a project corridor serve different road users (pedestrian, bike, transit, auto and freight). The multimodal performance of a corridor's cross-section design requires inputs and the outputs are in the form of a score for general corridor data on each road user type.

The Excel spreadsheet has nine individual worksheets. The first sheet provides an overview of the tool and its content. Sheets two through six seek inputs from the user. These sheets offer outputs for each modal score within the same sheet (which is very intuitive and handy for the user to see the results in one place). The seventh and eighth provide a summary and the scoring criteria, respectively.

For each of the modes assessed, the inputs in the General Inputs sheet are common to all modes. The information sought from the user on the corridor in this sheet includes AADT (average daily traffic), prevailing/posted speed, any raised median present, the total number of travel lanes, land use context (main streets, urban/walkable thoroughfares, small-town hamlet/village, commercial, suburban corridors or rural), and the presence of any high capacity transit.

The scoring criteria (as performance objective) for each mode varies between 1 and 4 (1 being the highest and 4 being the lowest score).

For pedestrian and bike modes, the scoring criteria are based on the Streetscore+ methodology developed by Fehr and Peers ([17]). StreetScore+ adopts the "weakest link" principle and 1-4 four scoring system by the Mekuria, Furth, and Nixon (2012)[18].

Some eight transit stop amenities determine transit score. The user checks the amenities if they are present at the "weakest" bus stop are: sign/identifier, shelter, lighting, real-time arrival display, trash receptacle, raised concrete platform, dedicated transit lanes, transit signal priority, continuous sidewalk, bench, bike parking, detectable warning strip, adjacent sidewalk, and queue jumps.

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[15] "SEMCOG, the Southeast Michigan Council of Governments and MDOT, the Michigan Department of Transportation", accessed on June 20, 2022. https://semcog.org/mmtool

[16] https://gis.semcog.org/portal/apps/webappviewer/index.html?id=a4ace662f6ea4a538c53202ff19b847a

[17] https://www.fehrandpeers.com/streetscore/

[18] Mekuria, M. C., Furth, P. G., & Nixon, H. (2012). Low-stress bicycling and network connectivity. Mineta Transportation Institute

Auto score is calculated based on the capacity assumption of the lane, peak hour factor, volume to capacity ratio of the road, level-of-service of the road, and land use context.

Freight score is calculated based on curb lane width, other special considerations (such as loading frequency from the street, mountable curb, etc.), and land-use context.

Screenshots of tables from the tool used for calculating scores are presented below in Figures A1-A5.

PEDESTRIAN INPUTS	
PED, SCORE 1	
Detached Sidewalk	
Prevailing Speed	Buffer >= 14 ft, <= 35 MPH / < 14 ft, <= 30 MPH
No. of Travel Lanes	Buffer >= 14 ft, 2-5 / < 14 ft, 2-3
Buffer Quality	Lush landscaping, parklet
Landscape Buffer and Street Trees	Continuous
Usable Sidewalk Width	>= 10 ft
Sidewalk Quality	Even, smooth surface
Sidewalk Accessibility	No driveways
Lighting	Pedestrian-scale
Heavy Vehicles	<= 5%
Active Building Frontage	Majority of sw has active building
Crossing Spacing	<= 400 ft
Special Considerations	None
Crossing Improvements	Any 2

Fig. A1. Pedestrian Score reference table (sample only)

BIKE, SCORE 1		
In-Road Protected Lane	***One-way***	***Two-way***
Buffer Width	>= 6 ft OR continuous barrier	
Barrier Type	25 MPH, painted buffer or more substantial for higher speeds	
Usable Bike Lane Width	>= 6.5 ft	>= 10 ft
Curbside Management	Vehicle loading planned through design	
Mid-Block Conflicts	<= 2 conflict points/block AND low volume OR raised crossings	
Special Considerations	None	

Fig. A2. Bike Score reference table (sample only)

TRANSIT		
Score		***High Capacity Transit***
1	Any 8, must include sign/identifier, shelter and sidewalk	Any 8, must include sign/identifier, shelter and sidewalk, any 1 of HCT
2	Any 5, must include sign/identifier and sidewalk	Any 5, must include sign/identifier and sidewalk
3	Any 3, must include sign/identifier and sidewalk	Any 3, must include sign/identifier and sidewalk
4	All other scenarios	All other scenarios

Fig. A3. Transit Score reference table (sample only)

AUTO	*V/C*	*Score*
LOS		
A	0.00-0.50	1
B	0.51-0.70	1
C	0.71-0.80	1
D	0.81-0.90	2
E	0.91-0.99	3
F	>1	4

Fig. A4. Automobile Score reference table (sample only)

FREIGHT	
Score	
1	12' or more; <=1 special consideration
2	11 to 12'
3	11'; 2 special considerations
4	11' or less

Fig. A5. Freight Score reference table (sample only)

A.2. Transportation Equity Scorecard Tool (TEST)

The TEST was developed by the Center of Urban Transportation Research (CUTR) at the University of South Florida (USF) under the sponsorship of the Center for Transportation Equity Decisions and Dollars (CTEDD) to assist organizations in advancing equity in project screening and prioritization ([19]). The tool is designed to assist MPOs and local governments in formulating projects that advance the needs of communities of concern (COCs) with a focus on addressing the transportation needs of disadvantaged populations (e.g., safety, mobility, affordability, health, and access to opportunity). Two Excel-based versions of the scorecard are available for project evaluation. An automated tool version automatically generates scores based on selected responses, and the second, non-automated version requires users to input scores manually. The screenshot image below from the spreadsheet tool sheet highlights scores assigned for reference for various equity categories.

Define COCs

[0] if project serves no concentration of COCs, [+1] if project serves medium to low concentration of COCs , [+2] if project serves high concentration of COCs, [-10] if project impacts high concentration of COCs

[+2] if project has significant impact

Category	Factor	Criteria	Basic Score Points (COCs) (Max Point=2 for each of the criteria)	Weighted Score COCs*Impact (+2 for High Impact) (Max Point=4 for each of the criteria)
Access to Opportunity	Employment	Project improves access to employment opportunities.	0, +1, or +2	(0, +1, or +2)*(+2)
	Education	Project improves access to educational opportunities (e.g., higher education, job training, schools, daycare, after school programs).	0, +1, or +2	(0, +1, or +2)*(+2)
	Community Services and Shopping	Project improves access to community services and shopping areas.	0, +1, or +2	(0, +1, or +2)*(+2)
Health and Environment	Health Care	Project improves access to health care services.	0, +1, or +2	(0, +1, or +2)*(+2)
	Healthy Food	Project connects to grocery stores or markets that provide healthy and fresh food at affordable prices.	0, +1, or +2	(0, +1, or +2)*(+2)
	Environment	Project increases livability (e.g., community cohesion, streetscaping, green infrastructure, etc.) through design and/or mitigation measures.	0, +1, or +2	(0, +1, or +2)*(+2)
Safety and Emergency Evacuation	Safety	Project improves safety for pedestrians and bicyclists at high-crash locations.	0, +1, or +2	(0, +1, or +2)*(+2)
		Project improves safety at other (non-high crash) locations.	0, +1, or +2	(0, +1, or +2)*(+2)
	Emergency Evacuation	Project improves emergency evacuation (e.g., transit coordination, connections to shelters, etc.).	0, +1, or +2	(0, +1, or +2)*(+2)
Affordability	Housing	Project improves access to and from affordable housing.	0, +1, or +2	(0, +1, or +2)*(+2)
	Transportation	Project increases availability of affordable transportation options.	0, +1, or +2	(0, +1, or +2)*(+2)
	Housing and Transportation Costs	Project decreases the share of household income consumed by transportation and housing.	0, +1, or +2	(0, +1, or +2)*(+2)
Mobility	Active Transportation*	Project includes construction or improvement of sidewalks, trails, bike lanes, or other active transportation options.	0, +1, or +2	(0, +1, or +2)*(+2)
	Transit Access and Service	Project improves transit service and/or access, including first and last mile access.	0, +1, or +2	(0, +1, or +2)*(+2)
	Americans with Disabilities Act (ADA)	Project improves accessibility for persons with disabilities (e.g., transit stops, ADA curb ramps, audio-visual signals, driveway grade, etc.).	0, +1, or +2	(0, +1, or +2)*(+2)
Burdens	Adverse Impacts	Project has adverse impacts (e.g., cumulative or disproportionate impacts, creates a barrier, increases noise or emissions, increases displacement/gentrification etc.)	-10 or 0	(-10, 0)*(+2)
	* also advances health and environment	Total	30	60

(Source: CUTR, 2020)

[19] Final Report, "Transportation Equity Scorecard – A Tool for Project Screening and Prioritization", USF Center for Urban Transportation Research, June 3, 2020.

B. Performance Measures – Transit Corridor

Based on literature review, various performance measures and corresponding metrics have been compiled and presented in Table B1 below. These measures are for strategies addressing equity, sustainability, mobility, safety, and reliability for transit corridor planning ([20],[21],[22],[23],[24],[25],[26]).

Table B1: Potential performance measures and metrics to be evaluated for a transit corridor

	Measure	***Metric***
1	*Equity*	• Meeting requirements of the Americans with Disabilities Act (ADA) such as compliance and coverage of transit services (for example, distance between stops and proximity to disadvantaged communities). • Difference in total number of riders served before and after the project • Increase in stop-level accessibility • Accessibility and reach to a remote location • Ridership and boarding counts along the route (before and after the project) • Determine stop productivity • Number of stations by ADA accessibility • Coverage: ▪ Ability to reach goods, services, and activities (coverage of transit services) ▪ Percentage of population within given miles of transit ▪ Percentage of population within given miles of transit stations ▪ Percentage of rural counties with public transit service • Population served: ▪ Percentage of rural population with transit service ▪ Percentage of population (by income, race etc.) with transit service availability ▪ Percentage of transit stops that are ADA compliant ▪ Percentage of residents, major employers and schools served within one-quarter mile of a transit stop. (Distance

[20] Performance Metrics for the Evaluation of Transportation Programs, National Transportation Policy Project, 2009.

[21] Transit Cooperative Research Program (TCRP) Report 141: A Methodology for Performance Measurement and Peer Comparison in the Public Transportation Industry, 2010.

[22] Litman, T., 2015. Evaluating public transit benefits and costs. British Columbia, Canada: Victoria Transport Policy Institute.

[23] Establishing a Framework for Transit and Rail Performance Measures, Division of Transit and Rail, Colorado Department of Transportation, December 2012.

[24] Rodier, C. and Issac, E., (2016). Transit Performance Measures in California, Mineta Transportation Institute, MTI Report 12-58.

[25] Transit Cooperative Research Program (TCRP) Report 176: Quantifying Transit's Impact on GHG Emissions and Energy Use—The Land Use Component, 2015.

[26] Quantifying the Results of Key Transit Investments, Preliminary Investigation, Caltrans Division of Research, Innovation and System Information, 2018.

		measured as actual walking distance via the network). • Connectivity: ▪ Number of transit stops ▪ Number of intermodal stations ▪ Number of communities connected
2	*Sustainability/Green House Gas (GHG) Emissions*	• GHG emissions for zero-emissions buses and diesel fleets. • Metrics under the Low Carbon Transit Operations Program (LCTOP) semiannual reporting requirements • Estimate emissions associated with land use and development (such as VMT) • Engine size or type to provide guidance on vehicle purchases that would assist in lowering GHG emissions. • Fuel type of new versus displaced vehicles to assess reductions in GHG emissions • Changes in service miles, hours and the amount of fuel consumed on an annual basis • Vehicle fuel efficiency based on mile per gallon
3	*Mobility*	• Expansion of the transit fleet or transit network • Changes in ridership and boardings • Changes to travel times for existing riders • Changes in passenger trips for a project (route and service) • Effectiveness - First/last mile connection • Quality of Service ▪ Frequency – Number of transit trips daily (on a typical weekday, Saturday, Sunday) ▪ Frequency – Number of passenger rail trips daily (on a typical weekday, Saturday, Sunday) ▪ Frequency – Number of transit service hours daily (on a typical weekday, Saturday, Sunday) ▪ Frequency - Number of transit service days annually ▪ Connectivity – Number of timed-transfer stops between intercity passenger rail and local bus transit service, or between the same transit mode types. ▪ Reliability – Percentage of transit trips on time ▪ Reliability – Percentage of passenger rail trips on time ▪ Percent of fleet with (wi-fi, on-board restrooms, etc.) ▪ Percent of transit stations with (indoor waiting areas, vending machines, restrooms, etc.) ▪ Percent of agencies using real-time passenger information systems • Mode Share ▪ Passenger-miles on transit bus (percentage or number) ▪ Passenger-miles on rail transit (percentage or number) ▪ Total passenger-miles on transit (percentage or number) ▪ Boardings per service hour
4	*Safety and Security*	• Safe entry and departure of vehicles and passengers • Safety and security measures

		• Key performance indicators (KPIs) related to safety, such as preventable accidents • Operator safety in terms of traffic level, lighting, and other factors • Number of accident reports and problem road calls • Traffic level, lighting, and other factors • Incidents ▪ Number of incidents (per VMT, per Year, per 1,000 passenger trips) (by severity) ▪ Number of incidents at at-grade rail crossings • Facility ▪ Percentage of rolling stock with safety features (driver cam, passenger cams, equipment, etc.) ▪ Percentage of at-grade crossings with active warning protection • Security ▪ Percentage of transit bus stops/ transfer points/stations with security features such as lighting, security staff, or CCTV ▪ Percentage of passenger rail stops/transfer points/stations with security features such as lighting, security staff, or CCTV ▪ Percentage of facilities that meet FTA security guidelines • Casualty and liability cost per vehicle mile
5	*Reliability/Service Quality*	• Strategy offers increased services and provide on-time performance • Rider satisfaction with reliability and service quality • Mean distance between failures, on-time performance, and number of complaints • Complaint statistics on rider satisfaction • On-time performance • Schedule adherence • Average system speed (or road speed limits) • Excess wait time • Passenger loading • Overall satisfaction • Number of complaints per 1,000 boardings • Number of compliments per 1,000 boardings • Call-center response time • Missed trips • Service span • Average system peak headway • Revenue miles per urban area sq. mi • Revenue miles (hours) per capita • Percent of fleet with ramps/low-floor

C. Performance Measures – Freeway Corridor

Table C1: Performance measure freeway corridor (Source: NCHRP SYNTHESIS 311[27])

Performance Measure	Typical Definition
Level of service (LOS)	Qualitative assessment of highway point, segment, or system using A (best) to F (worst) based on measures of effectiveness
Traffic volume	Annual average daily traffic, peak-hour traffic, or peak-period traffic
Vehicle-miles traveled	Volume times length
Travel time	Distance divided by speed
Speed	Distance divided by travel time
Incidents	Traffic interruption caused by a crash or other unscheduled event
Duration of congestion	Period of congestion
Percent of system congested	Percent of miles congested (usually defined based on LOS E or F)
Vehicle occupancy	Persons per vehicle
Percent of travel congested	Percent of vehicle-miles or person-miles traveled
Delay caused by incidents	Increase in travel time caused by an incident
Density	Vehicles per lane per period
Rail crossing incidents	Traffic crashes that occur at highway–rail grade crossings
Recurring delay	Travel time increases from congestion; this measure does not consider incidents
Travel costs	Value of driver's time during a trip and any expenses incurred during the trip (vehicle ownership and operating expenses or tolls or tariffs)

Table C2. Recommended core freeway performance measures (Source: NCHRP Project 3-68[28])

Performance Metric	Definition
Capacity Bottlenecks (Activity-Based)	• Geometric Deficiencies Related to Traffic Flow (Potential Bottlenecks) : Count of potential bottleneck locations by type • Major Traffic- Influencing Bottlenecks: Count of locations that are the primary cause of traffic flow breakdown on a highway section, by type
Throughput (Quality of Service)	• Throughput – Vehicle: Number of vehicles traversing a freeway in vehicles

[27] NCHRP SYNTHESIS 311, Performance Measures of Operational Effectiveness for Highway Segments and Systems, 2003.
[28] NCHRP Project 3-68, Guide to Effective Freeway Performance Measurement: Final Report and Guidebook (2007).

	• Throughout – Persons: Number of persons traversing a freeway • Vehicle-Miles of Travel: The product of the number of vehicles traveling over a length of freeway, times the length of the freeway • Truck Vehicle-Miles of Travel: The product of the number of trucks traveling over a length of freeway, times the length of the freeway • Lost Highway Productivity: Lost capacity due to flow breakdown – the difference between measured volumes • on a freeway segment under congested flow versus the maximum capacity for that segment
Customer Satisfaction (Quality of Service)	• Worst Aspect of Freeway Congestion • Satisfaction with Time to Make Long-Distance Trips Using Freeways
Safety (Quality of Service)	• Total Crashes: Freeway crashes as defined by the State, i.e., those for which a police accident report • form is generated • Crash Rate: Total freeway crashes divided by freeway VMT for the time period considered
Ride Quality (Quality of Service)	• Present Serviceability Rating (PSR): The general indicator of ride quality on • pavement surfaces. • International Roughness Index (IRI): Cumulative deviation from a smooth surface
Environment (Quality of Service)	• Nitrous Oxides (NOx) Emission Rate: Modeled NOx attributable to freeways divided by freeway VMT • Volatile Organic Compound (VOC) Emission Rate: Modeled VOC attributable to freeways divided by freeway VMT • Carbon Monoxide (CO) Emission Rate: Modeled CO attributable to freeways divided by freeway VMT • Fuel Consumption per VMT: Modeled gallons of fuel consumed on a freeway divided by freeway VMT
Incident Characteristics (Activity-Based)	• No. of Incidents by Type and Extent of Blockage Incident Duration: The time elapsed from the notification of an incident to when the last responder has left the incident scene • Blockage Duration: The time elapsed from the notification of an incident to when all evidence of the incident (including responders' vehicles) has been removed from the travel lanes • Lane-Hours Loss Due to Incidents: The number of whole or partial freeway lanes blocked by the incident and its responders, multiplied by the number of hours the lanes are blocked
Work Zones (Activity-Based)	• No. of Work Zones by Type of Activity: The underlying reason why the work zone was initiated: 1) resurfacing only; 2) RRR; 3) lane addition w/o interchanges; 4) lane additions w/interchanges; 5) minor crosssection; 6) grade flattening; 7) curve flattening; 8) bridge deck; 9) bridge superstructure; 10) bridge replacement; and 11) sign-related • Lane-Hours Lost Due to Work Zones: The number of whole or partial freeway lanes blocked by the work zone, multiplied by the number of hours the lanes are blocked

	• Average Work Zone Duration by Type of Activity: The elapsed time that work zone activities are in effect • Lane-Miles Lost Due to Work Zones: The number of whole or partial freeway lanes blocked by the work zone, multiplied by the length of the work zone
Weather (Activity-Based)	• Extent of highways affected by snow or ice: Highway centerline mileage under the influence of uncleared snow or ice multiplied by the length of time of the influence • Extent of highways affected by rain: Highway centerline mileage under the influence of rain multiplied by the length of time of the influence • Extent of highways affected by fog: Highway centerline mileage under the influence of fog multiplied by the length of time of the influence
Operational Efficiency (Activity-Based)	• Percent Freeway Directional Miles with (traffic sensors, surveillance cameras, DMS, service patrol coverage) • Percent of Equipment (DMS, surveillance cameras, traffic sensors, ramp meters, RWIS) in "Good" or Better Condition • Percent of total devicedays out-of-service (by type of device) • Service patrol assists

D. Performance Measures – Freight Corridor

Table D1: Performance measures and selected metrics for freight performance (Source: NCFRP Report 10[29])

Performance Measures	**Details**	**Specific Metrics**
Freight Demand Measures	• Freight Volumes (tons of freight) • Containerized Imports/Exports (millions of loaded TEUs)	
Freight Efficiency Measures	• Interstate Highway Speeds • Interstate Highway Reliability Measure • Trend Line of Top Interstate Bottlenecks • Logistics as a Percentage of GDP	• Travel time or difference in travel times (minutes or seconds) • Travel rate (travel time divided by travel distances) • Delay rate (minutes per mile) • Total delay (person hours, vehicle hours)

[29] NCFRP Report 10, Performance Measures for Freight Transportation, 2011.

		• Relative delay rate (delay rate divided by acceptable travel rate • Delay ratio (delay rate divided by actual travel rate) • Miles of congested roadway • Miles of congested travel • Travel Time Index, which compares peak period and free-flow travel conditions
Freight System Condition Indicators	• National Highway System (NHS) Bridge Structural Deficiencies • NHS Pavement Conditions	
Freight Environmental Measures	• Truck Emissions • Particulates • Truck NOx Emissions • VOCs • Greenhouse Emissions	
Freight Safety Measures	• Truck Injury and Fatal Crash Rates • Highway–Rail At-Grade Incidents	Total Annual Large-Truck Fatal Crashes Large-Truck Fatal Crash Rate Per 100 Million VMT Number of crashes; Number of vehicles involved in crashes; Number of people involved and resulting fatalities and injuries; and Number of drivers involved Cost of crashes involving longer combinations; Cost of straight truck crashes; Cost of “property damage only” crashes Cost per crash involving a nonfatal injury Cost per crash involving a fatality
Freight Investment Measures	• Investment to Sustain NHS • Cost of Capital	

	• Estimated Capital to Sustain Freight Market Share	

Other general freight measures are economic prosperity ([30]), the tonnage of goods to/from ports, a payload of trucks for different commodities and widely used Truck Travel Time Reliability Index (**[31]**).

[30] Implementaton,- Strategies and Objectives and Freight Investments, California Freight Mobility Plan 2020. https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/freight-planning/cfmp-2020-final/chapter6a-3-a11y.pdf

[31] Multimodal Freight System Performance Assessment, California Freight Mobility Plan 2020. https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/freight-planning/cfmp-2020-final/chapter3b-a11y.pdf

E. Performance Measures – Complete Streets Corridor

Table E1. Complete streets corridor performance metrics and measures (Source: Broward MPO[32])

Goal	*Objectives*	*Metrics*	*Performance Measures*
1. Balanced Mobility	1.1 Increase the incidence of bicycling and walking by X% at X months post-baseline.	Mode Share	Change in Bicycle Counts
			Change in Pedestrian Count
	1.2 Increase the number of transit users by X% at X months post-baseline.	Transit Ridership	Boarding and alighting transit activity along the Corridor
	1.3 Provide X% new facilities for bicyclists and pedestrians that improves the roadway environment for all users at X months post- baseline.	Multimodal Facilities	Percentage of Sidewalks and Bicycle Lanes/Paths Facilities
			Multimodal Level of Service (MMLOS)
2. Safety	2.1 Decrease crash injury and mortality rates for bicyclists and pedestrians by X% at X months post-baseline.	Crashes and Severity	Number of Crash Injuries and Mortalities
	2.2 Implement safe design countermeasures to calm traffic and reduce crashes by X% at X months post-baseline.	Vehicle Speeds	Change in Actual Automobile Speeds
		Safer Facilities	Number and Value of Crash Modification Factors (CMFs) and Crash Reduction Factors (CRFs) from Design Countermeasures
3. Health and Sustainability	3.1 Reduce vehicle emissions by X% and fuel consumption by X% through increased bicycle/pedestrian activity at X months post-baseline.	Environmental Impacts	Pounds of Carbon Dioxide Car Emissions Reduction from Bicycle and Pedestrian Usage
			Gallons of Fuel Savings
	3.2 Increase physical activity by X% at X months post-baseline.	Physical Activity	Number of Walking and Biking Trips
	3.3 Incorporate natural design elements throughout the corridor by X% at X months post-baseline.	Environmental Infrastructure	Percentage Tree Canopy Coverage
			Green Infrastructure for Water and Drainage
	3.4 Increase community support and satisfaction by X% at X months post-baseline.	User Satisfaction	Self-Reported User Satisfaction
4. Economic Vitality	4.1 Increase property values and business sales along the corridor by X% at X months post-baseline.	Property Values	Commercial and Residential Property Values
		Retail Activity	Business Sales Volume
	4.2 Reduce the number of parcel/business vacancies along the corridor by X%/$X at X months post-baseline.	Vacancies	Number of Vacant Parcels
	4.3 Reduce healthcare costs by X%/$X at X months post-baseline.	Healthcare Costs	Dollars of Healthcare Cost Savings from Bicycle and Pedestrian Usage

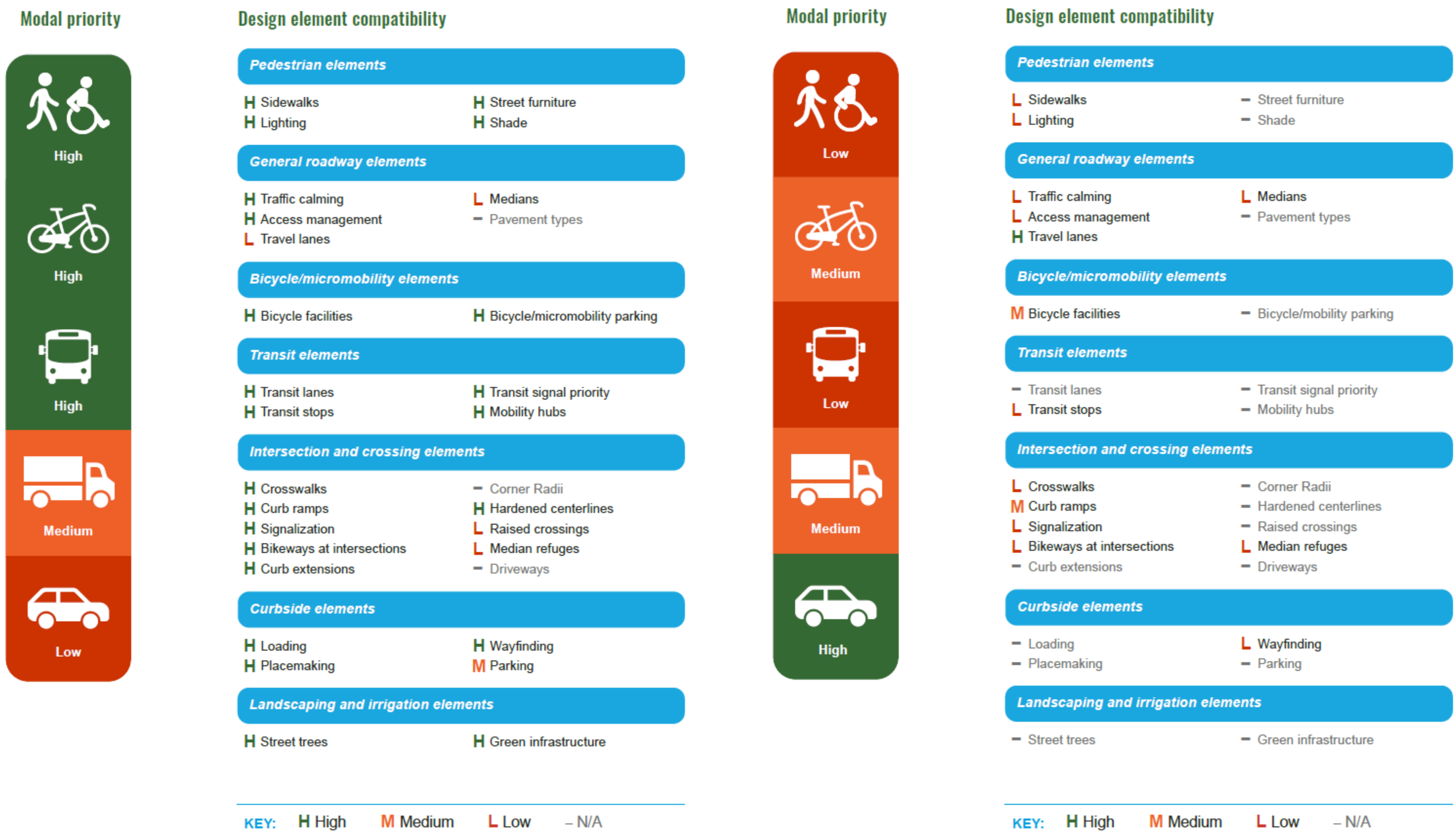
[32] Complete Streets Evaluation Toolkit - User Manual, Broward MPO, 2015. https://www.browardmpo.org/images/WhatWeDo/completestreetsinitiative/EvaluationToolkit.pdf

Table E2. Complete Streets Performance Indicators (Source: Toronto Centre for Active Transportation, 2015[33])

Complete Street Goal	*Outcome Performance Indicator (with desired effects)*
1. Active Transportation	Changes in pedestrian counts (increase) Changes in cycling counts (increase) Changes in transit ridership (increase) Changes in motor vehicle counts (decrease)
2. Level of Safety	Changes in collision severity (decrease) Changes in collision frequency (decrease) Changes in all collision types (pedestrian/bike vs. car) (decrease) Changes in traffic speeds (decrease)
3. Level of Service	Changes in transit travel time (decrease) Changes in motor vehicle travel times (and wait times) (decrease) Changes in average delay for a motor vehicle to clear a intersection (decrease) Multi-modal level of service (improve) Perceived safety and comfort (increase)
4. Surrounding Environment	Changes in local property values (increase) Changes in retail sales (increase) Changes in air quality (improve) Changes in physical activity (duration and frequency) (increase)

Other complete streets corridor plan involve prioritizing modes based on land-use context. For example, the toolkit from Denver Regional Council of Governments, Regional Complete Streets Toolkit, shows how the mode priorities changes for complete streets planning change based on Downtown Commercial and Mixed-use Streets and Mountain Road.

[33] COMPLETE STREETS EVALUATION, Understanding Complete Streets in the Greater Golden Horseshoe, Toronto Centre for Active Transportation, 2015. https://www.tcat.ca/wp-content/uploads/2015/03/Complete_Streets_Evaluation_19Mar2015-1.pdf



(a) (b)

Figure E1. Illustration of modal priority and design element compatibility for (a) Downtown Commercial and Mixed-use Streets and (b) Mountain Road ([34])

[34] Denver Regional Council of Governments, Regional Complete Streets Toolkit, Action Draft, 2021. https://drcog.org/sites/default/files/resources/TPO-RP-COMPLETESTREETS.pdf

Another important aspect of complete streets design is in the use of 'place-types' with geographic areas based on land use, the transportation system, and other characteristics to identify metrics. As per the California Smart Mobility Framework Guide, the five place types are Central Cities, Urban Communities, Suburban Communities, Rural Areas, Protected Land and Special Use Areas – along with the common metrics as defined in table below ([35]):

Table E3: Measures for complete street evaluations

Type	Description	Metrics	Examples
Central Cities	High density, mixed-use places with well-connected grid street networks, high levels of transit service, and pedestrian supportive environments.	• Avg pop density: 40,000* • Avg transit mode share: 33% • Avg road density: 28**	Downtowns of San Francisco, Oakland, San Jose, Sacramento, Los Angeles, San Diego
Urban Communities	Moderately dense places, mostly residential but with mixed-use centers. Housing is varied in density and type. Transit is available to connect neighborhoods to multiple destinations. Fine-grained network of streets with good connectivity for pedestrians and bicyclists.	• Avg pop density: 15,500 • Avg transit mode share: 10% • Avg road density: 26	Berkeley, Midtown and Curtis Park Sacramento, East and West Los Angeles, Santa Monica, Hillcrest and Little Italy San Diego
Suburban Communities	Primarily lower density residential with a high proportion of detached housing. Some interspersed retail and services, but little mixing of housing with commercial uses. Street networks often have poor connectivity. Low levels of transit service, large amounts of	• Avg pop density: 6,800 • Avg transit mode share: 3% • Avg road density: 19	Fremont, Milpitas, Pleasanton, Citrus Heights Sacramento, Roseville, Elk Grove, typical areas of Orange County and Inland Empire counties, Central Valley and Salinas Valley suburbs

[35] Caltrans SMART MOBILITY FRAMEWORK GUIDE, December 2020.

	surface parking, and inconsistent pedestrian networks.		
Rural Areas	Very low density places with widely-spaced towns separated by farms, vineyards, orchards, or grazing lands. Includes rural towns that provide a mix of housing, services, and public institutions in compact form that serve surrounding rural areas. May include tourist and recreation destinations which can significantly affect land uses, character, and mobility needs. Very limited modal choices.	• Avg pop density: 340 • Avg transit mode share: 1% • Avg road density: 3.5	Hilmar, Ferndale, Los Molinos, Gridley, Sutter Creek; much of the northern coast, Central Valley, and Sierra foothills outside metropolitan areas
Protected Lands and Special Use Areas	Lands protected from development by virtue of ownership, long-term regulation, or resource constraints. Also includes large tracts of single use lands that are outside of, or poorly integrated with, their surroundings.	• N/A	Protected lands include national forests and lands held in perpetuity by land trusts. Special use areas include airports, industrial facilities, military installations, some universities.

F. Capabilities and Limitations of Excel

The specifications and limitations of Excel as a spreadsheet tool for corridor planning have been summarized in Table F1 below. The information can help guide the size of data the tool can handle and the complexity of analysis that can be carried out using the tool.

Table F1: Excel specifications and limits (Source: Microsoft[36])

Feature	**Maximum limit**
Open workbooks	Limited by available memory and system resources
Total number of rows and columns on a worksheet	1,048,576 rows by 16,384 columns
Column width	255 characters
Row height	409 points
Page breaks	1,026 horizontal and vertical
Characters in a header or footer	255
Maximum number of line feeds per cell	253
Sheets in a workbook	Limited by available memory (default is 1 sheet)
Colors in a workbook	16 million colors (32 bit with full access to 24 bit color spectrum)
Named views in a workbook	Limited by available memory
Panes in a window	4
Linked sheets	Limited by available memory
Scenarios	Limited by available memory; a summary report shows only the first 251 scenarios

[36] https://support.microsoft.com/en-us/office/excel-specifications-and-limits-1672b34d-7043-467e-8e27-269d656771c3

Feature	Maximum limit
Changing cells in a scenario	32
Adjustable cells in Solver	200
Custom functions	Limited by available memory
Sort references	64 in a single sort; unlimited when using sequential sorts
Maximum limits of memory storage and file size for Data Model workbooks	32-bit environment is subject to 2 gigabytes (GB) of virtual address space, shared by Excel, the workbook, and add-ins that run in the same process. A data model's share of the address space might run up to 500 – 700 megabytes (MB), but could be less if other data models and add-ins are loaded. 64-bit environment imposes no hard limits on file size. Workbook size is limited only by available memory and system resources. Beginning with Excel 2016, Large Address Aware functionality lets 32-bit Excel consume twice the memory when users work on a 64-bit Windows operating system. For more information, see Large Address Aware capability change for Excel. Note: Adding tables to the Data Model increases the file size. If you don't plan to create complex Data Model relationships using many data sources and data types in your workbook, uncheck the Add this data to the Data Model box when you import or create tables, pivot tables, or data connections. For more information, see Data Model specification and limits.

G. Corridor Planning Tool FAQs

1. What are the tool file type and space needs?
Ans: The tool file type is an Excel macro-enabled workbook with a file size of around 270KB. The computer on which it is used should have Microsoft Excel 2010 or the latest version.

2. Will the tool crash with too many user actions or commands? When can that happen? Remedy?
Ans: The tool has been tested several times for more than 50 arbitrary metrics for each performance measure. The tool did not show any signs of a crash. But saving the work at frequent intervals is highly recommended as the data or information is entered into the tool.

3. Does the tool allow an analysis of multiple corridors present in a study area?
Ans: Yes.

4. Why five strategies?
Ans: For every strategy, five measures are evaluated. Each measure has a set of metrics that require data/information for a strategy evaluation. Therefore, managing five strategies is what we expect to be the maximum that is humanly possible without getting exhausted. However, a batch of five strategies can be analyzed at once using the tool if several strategies (more than five) need evaluation.

5. Why five performance measures (mobility, reliability, safety, sustainability, and equity)?
Ans: The measures were decided per the scope of work in the Contract.

6. Why a sensitivity analysis (option) is provided?
Ans: Often, data/information may have missing information and/or the user requires flexibility in choosing the metric weight(s) appropriately depending on the institutional knowledge and/or professional judgment. Sensitivity analysis allows the user to test a strategy as per the requirement.

7. What tool limitations must users be aware of or cautious about?
Ans: i) The labels for strategies printed in the charts of the Output sheet might overlap. User may drag and separate these overlaps if they occur. This will cause no changes to the output, and
ii) The clickable buttons should be used cautiously when adding or deleting a metric. The advantage of using the clickable buttons is that they allow quick addition or deletion of a metric row. However, once a metric row is added or deleted using the Ctrl+z on the keyboard will not get back to the original setting. This is because the buttons use a VBA code in the macro environment. For everything else, the tool will be supplemented with a manual to provide the guidance needed.

8. Does the tool require regular updates/revisions?
Ans: No updates are needed. The tool is static and will remain so. Only tweaking with the VBA code running in the background can alter any settings, if at all.

9. What features make the corridor planning tool innovative?

Ans: The Corridor Planning Tool (CPT) has been developed incorporating various innovative features of Microsoft Excel that make it highly interactive for the user for critical decision-making in the corridor planning process. The tool is fast in computations and easy to use due to the Visual Basic Application (VBA), a subset of the powerful Visual Basic programming language running in the background, for all calculations related to performance measure evaluations and the corresponding outputs displayed through charts. The VBA enables the automation of strategy evaluations without requiring the user to know VBA code or computer programming.

10. What specific problem does the tool solve, and how is it different from existing Excel or other software tools?

Ans: The CPT provides quick preliminary insights into the strategies or projects that would meet the requirements of a System planner for corridor planning.

Successful corridor planning often requires comprehensive multimodal evaluations of various performance measures (such as mobility, reliability, safety, etc.) of the corridor. Currently, if developed in Excel, most existing tools for multimodal corridor analysis are of limited/specific utility. While other techniques require simulation using travel demand model (TDM) software packages with multimodal transportation network data inputs on origin-destination information, network description, and different data needs for calibration of models. And the performance measure outputs with computations are carried out ‘behind the scenes’. Analyzing a handful of strategies with multimodal network changes can take significant time to obtain outputs. In addition, a user with TDM software must have a basic knowledge of transportation planning algorithms to analyze a set of strategies for a corridor.

The CPT, on the other hand, can have a broad reach and use as it is a spreadsheet-based tool that is highly flexible and user-friendly, requiring only basic knowledge of Microsoft Excel and the knowledge of the corridor to be analyzed by a System planner. A series of strategies (scenarios or projects) can be evaluated for performance measure assessments for a corridor as soon as the inputs with assigned measure and metric weights are entered. Often, these weights are available to a planner through surveys, public opinions, rule-of-thumb, or using best practices in planning. Optimal strategies as outputs are recommended using the CPT that a user (or a System planner) can review for effective decision-making in further developing and implementing a strategy for a corridor.
