ABOUT: COLORADO INDUCED TRAVEL CALCULATOR

The following page documents key background information, data sources, inputs, and methodological considerations. Please reach out to the analysis team with any follow-up questions or requests for data.

Calculator Overview and Purpose

RMI has developed and calibrated the induced travel calculator to evaluate the impacts of road widenings in Colorado, including their effect on state-wide vehicle miles traveled (VMT) and their emissions impacts. The calculator builds on analysis and methodology first published by Jamey Volker and Susan Handy at the University of California-Davis to calculate the induced travel impacts of lane mile additions in California metros and counties. It was also recently extended by Joe Cortright to Portland, Oregon.

The calculator will enable users to estimate long-run induced VMT (i.e., 5 to 10 years) from capacity expansions of large roadways (interstate highways, state highways, and arterials) in Colorado urbanized areas based on existing lane mileage and VMT data. Drawing from the body of literature estimating the relationship between VMT and lane mileage increases on these roads, it applies a ratio of 1.0—meaning a 1 percent increase in lane mileage yields a 1 percent increase in VMT, consistent with the literature discussed below. The calculator outputs a reasonable estimate for VMT induced at the appropriate order of magnitude for a given area.

The calculator is not intended as a substitute for more granular traffic modeling or simulations—but rather as a tool that can effectively translate well-established induced travel demand literature to an informed understanding of the impacts of road expansions.

Background on Induced Travel

The following background information and explanation on the induced travel phenomena is courtesy of Handy and Volker of the National Center for Sustainable Transformation at UC Davis. **The following passage helps characterize the state of the induced demand literature that underlie this tool.**

> Attempts to address traffic congestion commonly rely on increasing roadway capacity, e.g., by building new roadways or adding lanes to existing facilities. But studies examining that approach indicate it is only a temporary fix. They consistently show that adding roadway capacity in congested areas actually increases network-wide vehicle miles traveled (VMT) by a nearly equivalent proportion within a few years, reducing or negating the initial congestion relief. That increase in VMT is called "induced travel."
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> The induced travel concept is not new (see the "fundamental law of highway congestion" Anthony Downs suggested in 1962). Indeed, it is explained by the bedrock economic principles of supply and demand: "adding capacity decreases travel time, in effect lowering the 'price' of driving; when prices go down, the quantity of driving goes up" (Handy and Boarnet, 2014a).
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> The magnitude of the induced travel effect is commonly measured as the elasticity of VMT with respect to lane miles:
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> $$Elasticity = \frac{\%\ Change\ in\ VMT}{\%\ Change\ in\ Lane\ Miles}$$
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> The greater the elasticity, the greater the increase in VMT from a given increase in roadway capacity. An elasticity of 1.0 indicates that a given percent increase in lane miles will cause the same percent increase in VMT.

Most recent studies have estimated elasticities in the same ballpark, despite using a range of methods to control for other VMT-inducing factors and the bidirectional relationship between VMT and capacity expansion. In general, the studies show that a 10 percent increase in roadway capacity is likely to increase network-wide VMT by 6 to 10 percent (an elasticity of 0.6 to 1.0) in the long run (5 to 10 years), with greater elasticities for expansions of major highways (e.g., interstates) than for capacity increases on other roadways. These longer-term elasticities account for short-run shifts in travel (as people take advantage of the increased capacity and travel speed by driving more), as well as longer-run dispersion of residential and business location and development.

For more information on the induced travel and other impacts of highway expansion, see Handy (2015) and Handy and Boarnet (2014a). For a summary of key studies estimating the elasticity of VMT with respect to lane miles, see Handy and Boarnet (2014b). Please also see the References section below for a list of relevant studies.

Methods Explanation

Consistent with the methodology of previous induced demand calculators, induced VMT is estimated using the following equation:

$$\Delta\mathrm{VMT} = \mathrm{elasticity} * \frac{\mathrm{VMT}}{\mathrm{lane.\,mi}}\,\Delta\,\mathrm{lane.\,mi}$$

Data sources and specifications for VMT and lane mileage inputs are 2019 lane mileage and daily VMT data reported by the Colorado Department of Transportation on an urbanized area basis by facility type, as is similarly reported in the Highway Performance Monitoring System (HPMS). Note that the lane mileage and VMT inputs all reflect the selected geographic area. Additional details are provided in the subsequent section.

The calculator uses an elasticity of 1.0 for lane additions to class 1 facilities (i.e., interstates). As Handy and Volker have previously explained, the 1.0 elasticity is drawn from Duranton and Turner (2011), which also reflects several other studies that find convergent estimates of the impact of induced demand.

Handy and Volker's detailed summary of this work is available on the California Induced Travel calculator site. Notably, they highlight that the two-stage least squares regression represents an improvement in researchers' ability to address simultaneity bias. This preferred method finds a long-run elasticity of 1.03 for travel on interstate highways in the MSAs studied. Subsequent studies that build on these methods and introduce additional data continue to converge around a central travel demand elasticity of roughly one. This includes Melo et al. (2012), Graham et al. (2014), Hsu and Zhang (2014), and Hymel (2019). For an extensive and detailed review and discussion of the induced travel literature, including a comparison to analyses undertaken in the context of environmental review processes, please see Volker et al. (2020).

In light of this strong and consistent body of evidence around long-term impacts, the Colorado calculator also applies an elasticity of 1.0 for lane additions to class 2 or 3 facilities. Research that includes these roads within the scope of analysis also find elasticities at this order (e.g., Hymel [2019], Cervero and Hansen [2002], Duranton and Turner [2011]. Acknowledging that prior iterations of this tool have incorporated a slight downward adjustment to the elasticity estimate for these roads, we choose to present a constant long-term elasticity estimate of 1 across road types, while underscoring the range of uncertainty around project-specific outcomes.

On net, research on induced travel demand shows that road networks converge around this dynamic, but as is the case with any measure of central tendency, project-by-project impacts may land higher or lower. In line with other analytical approach decisions, the analysis team evaluated the sensitivity of results to this assumption and found only marginal impacts.
Finally, note that the Colorado calculator uses urbanized areas as the unit of analysis for lane mile additions across facility types 1, 2, and 3. This is consistent with the methodologies of several studies that evaluate impacts of capacity expansions on non-interstate major roads, but is different from the approach used to develop the California calculator. The rationale for this divergence is as follows:

- **The need for county-level granularity does not as clearly extend to Colorado.** Cervero and Hansen's selection of counties in urbanized areas in California as the unit of analysis, which directly informs the California calculator inputs, stems from the need to capture relevant network effects without diluting impacts due to major overlapping metro areas. While this is a highly salient concern in California, it would be less logical rationale for analysis in Colorado, where major urbanized areas are generally distinct.
- **Reporting by urbanized area provides richer Colorado data sources.** The consistent use of urbanized areas as a unit

of analysis across class types enables the Colorado analysis to be conducted using the most complete CDOT data. The Roadway Statistics reported on the county-level by CDOT exclude city and county roads, leading to lower estimates of lane mileage and VMT for non-interstate roads than the HPMS submission, which is tallied by urbanized area.

- **The outcomes are relatively stable across assumptions.** Finally, the analysis team has conducted sensitivity checks regarding the impact of different units of analysis on calculation outcomes and concluded that the impact is relatively minor.

Calculation Overview

Further explanation of calculation inputs, guidance on interpretation, and analytical approaches is provided in the detailed bullets below:

- **Calculation Inputs:**
    - **Timing.** The lag between facility expansion and full induced VMT impacts is expected to be 5 to 10 years. As a mid-range simplifying assumption, the cumulative emissions impacts reported in the accompanying blog post assume impacts begin after 5 years.
    - **Elasticity**. The calculator utilizes an elasticity of 1.0 to estimate the impacts of lane mile additions across Class 1, 2, and 3 facility types, as documented and explained above. Note that induced VMT is reported in intervals of 10 million miles, which reflects in part the range of uncertainty around precise elasticity estimates. As previously noted, research on induced travel demand shows that road networks converge around this dynamic, but as is the case with any measure of central tendency, project-by-project impacts may land higher or lower.
    - **User Inputs/Scope.** The calculator should only be used to evaluate capacity expansions (lane additions, roadway lengthening, and new facility construction). The calculator can be applied to additions of general purpose, high-occupancy-vehicle (HOV), and high-occupancy toll (HOT) lanes.
        - Note that this analysis incorporates HOT lanes as a reasonable application of the induced demand literature, which previous analyses have not explicitly done. The rationale is as follows:
            1. Analysis of more recent trends in roadway expansions (i.e., studying networks that have incorporated HOT lane configurations) continue to converge around the same general elasticity.
            2. General intuition suggests that travel on HOT lanes should be less restricted than HOV lanes, given that regular occupancy vehicles may also select into them, which reasonably situates HOT lanes within the generalizable set of elasticity results around 1.0.
            3. The induced travel results are framed in a way that communicates a range of uncertainty on a project-specific basis. There are several factors—lane type included—that likely drive slightly higher or lower travel demand elasticities for a given set of circumstances, and the framing is intended to communicate that less granular level of precision.
- **Data Overview:**
    - **Source.** The calculator utilizes 2019 lane mileage and VMT data reported by CDOT on the urbanized area basis, consistent with the Federal Highway Administration's (FHWA's) Highway Reporting Monitoring System (HPMS) reporting.
    - **Facility Types.** The calculator can be used to estimate induced travel due to road expansions on Colorado roadways with FHWA functional classifications of 1, 2, or 3 (interstates, state highways, and arterials).
    - **Geography.** The calculator's use is limited to urbanized areas in Colorado with existing lane mileage of a given functional class. For example, the calculator could not be used to estimate an expansion in Class 1 facilities in the Boulder urbanized area because there are no Class 1 lane miles recorded there. The calculator output will clearly indicate when this is the case.
    - **Precision.** Induced VMT is reported annually and in intervals of 10 million miles. This reflects the nature of the

calculations, which are intended to provide a useful order-of-magnitude estimate based on well-established evidence of expected impacts.

- **Interpreting Results.**
    - Consistent with Handy and Volker's approach, "All estimates account for the possibility that some of increased VMT on the expanded facility is traffic diverted from other types of roads in the network." As they highlight, the research shows that "capacity expansion leads to a net increase in VMT, not simply a shifting of VMT from one road to another." (Handy and Boarnet, 2014a.)
    - As noted previously, the calculator provides a reasonable estimate for the net impact of capacity expansions. Project-specific outcomes may vary in pace and magnitude at margins, depending on a range of factors, and land either below or above a central elasticity of 1.0 by years 5 to 10. For example, a road expansion project to streamline a chokepoint may drive a different outcome than a lane widening project on a typical major road, increasing throughput potentially by even more than we have estimated. In another case, we would expect that the induced demand impact of lane-mile additions of toll-managed lanes will vary depending on the magnitude of the toll. The calculator's results do not describe differences across these dynamics but address the shared long-run impacts of adding capacity (and subsequently reducing the costs of driving).
    - To that end, local context and project-specific knowledge can help interpret the calculator outcomes and are particularly critical when it comes to designing solutions to highly localized and acute challenges.
- **Future Adaptation.** Note that this calculator itself represents an adaptation of existing methods to a new geography. As noted in previous iterations, continued efforts to build on and extend this work are welcome and highly feasible, given existing capacity and traffic data assets held by state DoTs and the generalizability of elasticity estimates from the research.

Additionally, the subsequent calculator's emissions outputs can be applied and interpreted according to the more detailed bullets below:

- **Cumulative Emissions.** Total cumulative emissions added are calculated under two sets of assumptions, both drawn from the Colorado Energy Policy Simulator, to estimate the impacts under the following scenarios:
    - The high climate ambition scenario accounts for a set of policies and assumptions that target mitigation investments consistent with a climate-safe future, including 100% electrification of new passenger vehicles by 2035 and rapid renewable power development.
    - The business-as-usual scenario reflects projected efficiency and electrification improvements and current policy measures.

  Additional information on these scenarios and underlying assumptions is easily accessed via the detailed EPS documentation. In addition, these calculations assume that construction on the lane mile additions input into the calculator start in 2021 and are complete by 2030. As a simplifying assumption, these calculations incorporate a five-year lag period between installation and induced demand to reflect the initial point at which the full or near-full induced demand effects may be felt.

  Cumulative emissions are calculated on both a direct and lifecycle basis, to showcase the additive impact of direct and indirect emissions from induced demand. The direct portion of the cumulative emissions footprint is calculated using scenario-specific trajectories for vehicle electrification, electricity emissions intensity, vehicle efficiency improvements, and travel demand growth from the Colorado EPS. Beyond the direct emissions impact, which reflects the emissions impacts of gasoline and diesel combustion, the lifecycle emissions calculation also incorporates upstream and manufacturing emissions:
    - **Upstream emissions** come from the production of gasoline and diesel, drawn from work done by the California Air Resources Board to utilize the Argonne National Lab's GREET tool and calculate lifecycle fuel emissions intensities.
    - **Manufacturing emissions** are associated with light-duty vehicle production, drawn from International Council of Clean Transportation (ICCT) estimates (note that HDV manufacturing emissions are not incorporated).

  Note that real-world lifecycle emissions impact will also include the emissions generated by the infrastructure assets

themselves, via production of building materials (e.g., concrete manufacturing, asphalt production), construction activities, operation and maintenance of infrastructure assets, and even disposal/end-of-use phase considerations. These may vary considerably with design and material choices; IPCC finds that in the United States, infrastructure-related emissions for light-duty vehicles range from 17 to 45 gCO2e per passenger kilometer (~27 to 72 gCO2e per mile).
Relative to cumulative transportation emissions generated from induced demand, these impacts would likely lead to a slight increase to our indirect lifecycle emissions estimates for Colorado. Additional impacts could occur if highway expansion facilitates construction of lower density residential and commercial development than would otherwise have occurred, but we did not quantify this. As such, ours is a conservative estimate.

In addition, emissions estimates are calculated to illustrate the additive emissions impacts of induced demand. They do not incorporate a counterfactual scenario analysis. The emissions impact of congestion pales in comparison to the impact of additional induced travel, especially given that road expansions are not a lasting solution for congestion. Moreover, we expect the emissions impact of congestion to diminish in the coming years as stop-start technology becomes increasingly common in the US vehicle fleet. As such, we find it appropriate to present the added emissions as a stand-alone calculation of impact.

- **Annual Emissions.** The calculator also outputs an estimate of the annual direct emissions generated by induced demand, which are calculated as a current snapshot (i.e., based on the most recent emissions and efficiency assumptions).
  - **The annual direct emissions snapshot** is calculated based on current conditions and emissions factors. These include: the breakdown of VMT by vehicle type on Colorado urban roads (as reported by FHWA for 2017, the most recent data vintage), the average current Colorado fuel efficiency levels (drawn from the Colorado Energy Policy Simulator), and energy and emissions intensity factors for gasoline and diesel (as published by the EPA).
  - **Annual emissions equivalencies are** calculated using factors documented via EPA's GHG Equivalencies Calculator and the annual direct emissions snapshot described above. Note that this calculation uses US-based factors—consistent with the EPA tool—rather than factors developed on a Colorado-specific basis. The factors and underlying documentation are available here.
- **Precision.** Like the estimates of induced demand, the estimated emissions are reported in intervals. For example, the cumulative emissions figures are rounded to the nearest hundred thousand metric tons.

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