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16. ABSTRACT

The passage of California Assembly Bill 32 (the Global Warming Solution Act of 2006), and California Senate Bill 375 (which requires regions to develop strategies to reduce vehicular travel by incorporating land use change scenarios) provides targets and a framework for reducing greenhouse gas (GHG) emissions in California. Additionally, California Senate Bill 391 requires Caltrans to assess how the Metropolitan Planning Organization's Sustainable Communities Strategies (SCS) implementation will influence the configuration of the statewide multimodal transportation system needed to achieve a statewide reduction of GHG emissions to 1990 levels by 2020, and 80 percent below 1990 levels by 2050.

The objective of this research effort was to provide Caltrans with tools to assist with prioritizing of which GHG emission reduction strategies for interregional travel California should focus on. Caltrans needed a better understanding of the potential magnitude of emissions reduction from strategies where data is available and developing level of confidence estimates for various strategies, and gauging the social/political acceptability of potential GHG strategies. Additionally, this research was to provide vital inputs, based on the current state of knowledge (in terms of elasticities and feasibility of various GHG reduction strategies), for the California Statewide Travel Demand Model which is a requirement for the California Transportation Plan (CTP).

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December 31, 2013

Final Report

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Executive Summary

In 2005 the governor of California issued Executive Order S-3-05 setting a long-term goal for California to reduce greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050. In 2006 California passed the first global warming legislation in the United States: the Global Warming Solutions Act or Assembly Bill 32 (AB 32). This legislation requires California to decrease greenhouse gas (GHG) emissions to 1990 levels by 2020. In 2008 California passed the Sustainable Communities and Climate Protection Act or Senate Bill 375 (SB 375), another landmark legislation designed to create a stronger link between regional land use planning and transportation planning via Sustainable Community Strategies (SCSs) or Alternative Planning Strategies (APSs) developed by the Metropolitan Planning Organizations (MPOs) showing how each MPO will meet the GHG reduction targets assigned by the California Air Resources Board. The Transportation Plan Act or Senate Bill 391 (SB 391), passed in 2009, requires the California Department of Transportation (Caltrans) to update the California Transportation Plan (CTP) by December 31, 2015 (and every 5 years thereafter), including how the state will achieve maximum feasible GHG emissions reductions in order to attain a statewide reduction of GHG emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050 (AB 32 and Executive Order S-3-05 goals). The bill requires the CTP to identify the statewide integrated multimodal transportation system needed to achieve these results.

This report seeks to provide Caltrans with additional information about strategies to improve system efficiency and lower vehicle miles traveled (VMT) to reduce GHG emissions from interregional travel. This research reinforces strategies developed and proposed by the California Transportation Plan Technical and Policy Advisory Committees and should assist Caltrans with planning and research agenda to strengthen strategies to reduce GHG emissions from interregional travel.

The results of a series of 14 expert interviews with representatives from some of the MPOs and Regional Transportation Planning Agencies (RTPAs) in California are reported here. In addition, a comprehensive literature review was conducted including 48 topics ranging from system efficiency, to behavioral change to strategies for reducing VMT. The goal was to provide Caltrans with tools to assist with: 1) prioritizing which GHG emission reduction strategies for interregional travel California should focus on; 2) understanding the potential magnitude of emissions reduction from strategies where data is available; 3) developing level of confidence estimates for various strategies, and; 4) gauging social/political acceptability of strategies.

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1. Introduction

In 2005 the governor of California issued Executive Order S-3-05 setting a long term goal for California to reduce greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050. In 2006, continuing its role as a leader in environmental stewardship, California led the nation by passing the first global warming legislation in the United States: the Global Warming Solutions Act or Assembly Bill 32 (AB 32). This legislation requires California to decrease GHG emissions to 1990 levels by 2020. This is approximately a 27 percent reduction from projected 2020 GHG emissions. The goal is to be reached using a phased-in approach beginning in 2012. According to the California Air Resources Board (CARB) transportation accounts for approximately 37% of GHG emissions in California.

In 2008 California passed the Sustainable Communities and Climate Protection Act or Senate Bill 375 (SB 375), another landmark legislation designed to create a stronger link between regional land use planning and transportation planning via Sustainable Community Strategies (SCSs) or Alternative Planning Strategies (APSs) developed by the Metropolitan Planning Organizations (MPOs) showing how each MPO will meet the GHG reduction targets assigned by CARB. The SCS GHG reduction targets are individual to each MPO, based on recommendations from the Regional Targets Advisory Committee (RTAC). SB 375 requires that transportation funding be consistent with approved SCSs. These targets are for both 2020 and 2035. Each MPO, as part of its Regional Transportation Plan (RTP), must complete an SCS that articulates a set of land use, housing, and transportation strategies to achieve its GHG targets.

Further strengthening California's commitment to reduce GHG emissions, the 2009 Transportation Plan Act or Senate Bill 391 (SB 391), requires the California Department of Transportation (Caltrans) to update the California Transportation Plan (CTP) by December 31, 2015 (and every 5 years thereafter), including how the state will achieve maximum feasible GHG emissions reductions in order to attain a statewide reduction of

GHG emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050 (AB 32 and Executive Order S-3-05 goals). The bill requires the CTP to identify the statewide integrated multimodal transportation system needed to achieve these results.

While SB 375 targets regional planning and GHG emissions, SB 391 addresses statewide GHG reductions from transportation, effectively bringing the whole California transportation system under AB 32 reduction goals. The bill requires the CTP to identify the statewide integrated multimodal transportation system needed to achieve these results.

The SB 375 regional SCS planning processes and Caltrans' effort under SB 391 to identify strategies to reduce GHG emissions from interregional travel have different timelines and planning horizons. However, Caltrans and the MPOs are sharing information and strategies to accomplish their respective goals under SB 391 and SB 375. This report seeks to provide Caltrans with additional information about strategies to improve system efficiency and lower vehicle miles traveled (VMT) to reduce GHG emissions from interregional travel. GHG reduction strategies pertaining to alternative fuels and advanced vehicle technologies were not addressed during this project.

Section 2 of this report provides background information for understanding interregional GHG reduction planning. Section 3 summarizes a series of expert interviews conducted with representatives from MPOs and Regional Transportation Planning Agencies (RTPAs) in California. Section 4 summarizes the results of a comprehensive literature review including 48 topics ranging from system efficiency, to behavioral change to strategies for reducing VMT. Finally, Section 5 concludes with recommendations.

2. Background

From a GHG policy planning perspective interregional travel includes all passenger travel that is not currently being managed by a previously designated MPO or RTPA. SB 375 excludes interregional travel meaning that MPOs do not need to measure or address GHG emissions from interregional travel in their SCS. RTPAs are not subject to SB 375 and therefore not addressed by the RTAC for SB 375. The RTAC report for SB 375 defines interregional travel as follows:[1]

- Trips that begin in one SB 375 MPO region and end in another SB 375 MPO region after crossing their shared boundary (MPO-to-MPO);
- Trips begin outside of an SB 375 MPO region, travel across some portion of the region, and end outside of the region (through trips);
- Trips that begin in an SB 375 MPO region but do not end in an SB 375 MPO region (interstate, international, tribal land, and military base trips); and,
- Trips that end in an SB 375 MPO region but do not begin in an SB 375 MPO region (interstate, international, tribal land, and military base trips).

Developing strategies to reduce GHG emissions from interregional travel can include a variety of situations ranging from rural highway travel to more urban travel between two previously designated regional planning agencies. Significantly more data exists regarding strategies to reduce VMT and improve system efficiency in urban areas than for interregional travel between urban centers. Historically urban centers have been the

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[1] Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375. A Report to the California Air Resources Board. Page 26. No date.

focus of air quality research and policy focusing on VMT reduction and congestion management. As a result:

1) Development of strategy and policy to reduce GHG emissions from interregional travel relies in large part on data developed under more urban conditions, and;
2) Success at the regional scale with strategy to reduce VMT and improve system efficiency, including SB 375, should confer GHG reduction benefits to interregional travel, although the magnitude may be limited and not easily measured.

SB 375 excludes GHG emissions from goods movement. Thus GHG emissions from goods movement (within regions and interregional) fall within the purview of statewide planning. Strategy to reduce GHG emissions from goods movement can focus on both the longer distance travel (interregional) and delivery into the urban areas (regional). Although MPOs are not required to address GHG emissions from goods movement, some have included goods movement strategies in their planning processes.

3. Expert Interviews

3.1 Background

In October and November 2013, researchers conducted 14 interviews with regional planning organizations throughout California to learn about their work to identify and develop strategies to reduce GHG emissions from transportation. By collecting qualitative information on their critical issues, challenges, and lessons, this research project hopes to inform Caltrans in its efforts to identify policies and strategies that can reduce interregional GHG emissions and ultimately incorporate those strategies into the state transportation plan.

The research team, in collaboration with Caltrans, developed a semi-structured interview questionnaire that covered the following subject areas:

- The agency’s role in reducing GHG emissions from transportation and the current status of relevant planning documents.
- The agency’s GHG reduction planning process, including selection of strategies, consideration of social and political acceptability of strategies, calculation of emissions, and technical modeling uncertainties.
- The agency’s efforts to estimate GHG reductions from interregional travel-related strategies, either through modeling or off-model approaches.
- The agency’s efforts to estimate GHG reductions from goods movement-related strategies, either through modeling or off-model approaches.
- Recommendations from the agency about interregional, goods movement, and other GHG-reduction strategies that should be developed in partnership with Caltrans or that Caltrans should lead.

Researchers sent the questionnaire to experts in advance of the interview if requested. Most interviews were between 45 minutes and one hour in duration. In general, there was not sufficient time to ask all the questions in the questionnaire (See Appendix A for the full questionnaire). Researchers prioritized the questions on interregional and goods movement strategies, followed by the questions about agencies' GHG reduction planning process.

Eleven MPOs and three Regional Transportation Planning Agencies (RTPAs) were interviewed. All counties in California have an RTPA and counties that have at least one urbanized area over 50,000 in population also have an MPO. A single MPO may serve more than one county and more than one urbanized area. The MPO interviews focused on the agencies' planning efforts to achieve their state-mandated targets. The RTPAs do not have any state-mandated GHG targets. These interviews focused on the agencies' voluntary strategies to reduce GHG emissions. One local air pollution district participated at the request of their local planning agency. Other attributes of the interviews included the following:

- In nine of the interviews, one expert from the agency participated.
- In four of the interviews, two experts from the agency participated.
- In one of the interviews, two experts participated – one from the local RTPA and one from the local air pollution control district.
- Thirteen of the experts had titles such as planner, associate planner, and senior planner.
- Five of the experts had titles such as principal planner, deputy planning director, and planning director.

The agencies ran the gamut in terms of population and urban/rural character. Experts were asked to characterize their agencies' regions in terms of population and density (i.e., rural versus urban). Five regions have a population between 50,000 and 199,000. Nine regions have a population greater than 200,000, including three very large urban regions. Experts from four regions with populations greater than 200,000, described their regions as a mix of rural and urban. All interviews were confidential and all responses are reported anonymously.

3.2 Expert Interview Key Findings

Key findings from the expert interviews are noted here in Section 3.2. A comprehensive summary of the expert interviews is provided in Section 3.3.

Agency roles in GHG reduction

- Most MPOs said they were following their legislatively assigned responsibility under SB 375 to prepare a Sustainable Communities Strategy (SCS) document that links land use and transportation strategies to achieve GHG reduction targets.
- The RTPAs said they do not have GHG targets or policies but are working to indirectly reduce GHG emissions.

GHG reduction targets and barriers

- Nearly all of the MPOs plan to either meet or exceed their state-assigned GHG emissions targets through their SCS.
- Most MPOs also noted that there are significant challenges that may impact their ability to meet their GHG targets, such as funding and political dynamics.

Agency planning processes

- The most common approaches used by MPOs in selecting GHG reduction strategies were collaborating with local jurisdictions; modeling of strategies and scenarios to assess their GHG benefits; conducting public and stakeholder engagement and outreach; and evaluating the cost of strategies and the availability of funding.
- The RTPAs indicated that GHG reduction was a much lower priority in their planning processes.
- MPOs used similar approaches to achieve political and social buy-in for their plans -- in particular, conducting public/stakeholder outreach and working with local jurisdictions.

GHG emissions calculations

- To determine baseline year (2005) carbon dioxide emissions for their SCS documents, most MPOs said they used their agency's transportation model and/or the Emission Inventory/Emission Factors (EMFAC) model from CARB.

- All MPOs said they counted the GHG emissions from the vehicle classes – automobiles and light trucks – prescribed under the SB 375 mandate, and all said that they followed a statewide emissions attribution methodology determined by CARB.
- MPOs described many uncertainties with their GHG modeling, such as lack of adequate tools to assign responsibility for interregional trips, lack of transportation data, changing travel behaviors, and uncertainty as to where future development will occur.
- Most MPOs said they had strategies that didn't fit into their modeling processes, and they had to use off-model GHG reduction estimates for these strategies.

Social and Political Outreach

- Most MPOs and RTPAs noted approaches for winning the support of local jurisdictions, including regular meetings with elected officials, collaboration with local agencies or committees comprised of local officials, and sourcing strategies from local general plans and other local agencies.

- Nearly all MPOs and RTPAs said that their plans had strong support from the public and elected officials by the end of their plan development cycles.

Interregional strategies

- All agencies are including interregional GHG reduction strategies in their plans. The most common strategies are land-use/density approaches, rail, interregional transit, high-speed rail, and transportation demand management.
- Agencies are employing a mix of interregional strategies that were modeled and strategies evaluated off-model.
- Most respondents were unable to provide elasticities for strategies, but said Caltrans could contact their agency for further technical information about their modeling.
- Several agencies discussed their inability to accurately measure interregional GHG emissions due to the lack of an acceptable statewide model. [Caltrans has since stated that an acceptable statewide model will be made available to the MPOs Spring 2014.]
- Several agencies recommended that Caltrans take more leadership on completing the Statewide Travel Demand Model, so that agencies can make more accurate estimates of interregional travel-related GHG emission reductions.

Goods movement strategies

- Nearly half of the agencies are not including any goods movement strategies in their GHG reduction plans.
- For those agencies that do include goods movement strategies in their plans, some of the strategies are being modeled while others are not. Most respondents said that Caltrans could contact their agency for further technical information.
- Agencies provided a variety of suggestions for goods movement strategies that Caltrans could lead, including statewide coordination on establishing inland ports, expansion of rail, and goods movement corridors.

Additional Recommendations on GHG Reduction Strategies

- MPOs recommended that Caltrans help coordinate uniform data sources and modeling platforms across MPOs and state agencies.
- Participants observed that most state transportation money seems to go to road projects and recommended that Caltrans become a more multimodal agency and invest in other types of transportation and land use planning, including active transportation projects such as biking and walking modes.
- It was suggested that Caltrans could compile up-to-date, locally relevant data on goods movement to provide local planning agencies with better information.

3.3 Expert Interview Comprehensive Summary

3.3.1 AGENCY GHG REDUCTION ROLES

MPO Role in GHG Reduction

Most MPO respondents cited their legislatively assigned responsibility to prepare an integrated planning document – the SCS – that links land use and transportation strategies to achieve specific GHG reduction targets. The participating MPOs included a mix of agencies that had recently adopted their RTP/SCS, and agencies that were in the midst of the RTP/SCS development process. The latter group planned to adopt their RTP/SCS in 2014, 2015, or 2016.

Two respondents from smaller rural MPOs added that this planning effort reflects and reinforces the strategies of local jurisdictions in the region. Along similar lines, another expert from a more urban region emphasized that it was important for the MPO to work with local agencies on the SCS, since they are the organizations making land use changes that impact SB 375 implementation.

Several experts, representing a variety of regional sizes and densities noted that their agencies administer other pre-existing programs that reduce GHG emissions that are independent of the SB 375 mandate. In some cases, these programs are being counted in the GHG reductions in the SCS document. The agencies may be implementing these additional programs on a voluntary basis and/or to facilitate implementation of other state programs, such the low-carbon fuel standard.

RTPA Role in GHG Reduction

The three participating RTPAs were in the middle of their RTP development process and expected to adopt their documents in either 2014 or 2015.

The RTPA and local air district experts all indicated that while they do not have any direct state mandate for GHG reductions, nor any specific agency-level GHG targets or policies, they are working to indirectly reduce GHG emissions. Nevertheless, one respondent emphasized that the agency is limited in terms in of how it can address GHG reduction in its RTP, due to lack of implementation funds and data.

Another respondent stressed the importance of packaging GHG reduction initiatives in other terms to make them politically palatable in a conservative region. Since "mentioning greenhouse gases by name is not something that gets a good reception," this respondent's agency frames emissions reductions initiatives in broader air quality terms such as smog and smoke. Along the same lines, another subject's agency sometimes packages GHG reduction efforts within road safety initiatives, because safety is considered a high priority among local policymakers.

One RTPA has a planning effort underway that does not explicitly address GHG emissions reductions, but can achieve GHG goals through efforts to reduce VMT and improve air quality.

An RTPA located within the jurisdiction of a large MPO region develops transportation projects for its RTP that later get incorporated into the SCS of the MPO. The MPO ultimately handles the GHG emissions reduction calculations for these projects.
A respondent from a small air district discussed the agency's environmental review process that requires projects to identify transportation emissions, among other types of emissions. The district collects an emissions mitigation fee from developers when new developments are being built, and the fee revenues, along with grants, are put toward transportation initiatives to reduce emissions, indirectly impacting GHG. The same district has a rule requiring reduction of particulates, NOx, and other non-GHG air emissions that can indirectly reduce GHG.

3.3.2 GHG REDUCTION TARGETS AND BARRIERS

As part of the SCS development process, CARB has assigned GHG targets to MPOs for 2020 and 2035. These targets are expressed as a per capita percentage decrease or increase compared to 2005 levels. The MPOs interviewed for this project have 2020 targets ranging from a 1% increase to an 8% decrease, as shown in Table 1.

Table 1: 2020 Target GHG Reductions for MPOs and Anticipated Reductions per SCS

AGENCY	Status of SCS	CARB target, 2020	Agency SCS plan, 2020
Butte County Association of Governments	in preplanning for RTP/SCS; will kick off project in July 2014 and complete in December 2016	+1%	-2%
Fresno Council of Governments	about to select a preferred scenario for SCS. The final adoption for RTP/SCS will be June 2014.	-5%	SCS not adopted
Kern Council of Governments	expected adoption of RTP/SCS in June 2014	-5%	SCS not adopted
Metropolitan Transportation Commission	all final approvals for RTP/SCS are in; final printed glossy by December 2013	-7%	-10.4%
San Diego Association of Governments	adopted last RTP/SCS in October 2011; started next RTP/SCS, expected completion in 2015	-7%	-14%
San Joaquin Council of Governments	in public process for RTP/SCS; expected completion in 2014	-5%	SCS not adopted
Santa Barbara County Association of Governments	adopted RTP/SCS in August 2013	0%	-10%
Shasta Regional Transportation Agency	50% complete with RTP/SCS; expected to complete end-2014	0%	SCS not adopted
Southern California Association of Governments	adopted RTP/SCS in June 2013	-8%	-9%
Stanislaus Council of Governments	policy board has selected preferred scenario of RTP/SCS; agency is developing document narrative	-5%	SCS not adopted
Tahoe Regional Planning Agency/Tahoe Metropolitan Planning Organization	adopted RTP/SCS at the end of 2012	-7%	-12%

The MPOs 2035 targets range from a 1% increase to a 15% decrease in GHG emissions, as shown in Table 2.

Table 2: 2035 Target GHG Reductions for MPOs and Anticipated Reductions per SCS

AGENCY	Status of SCS	CARB Target, 2035	Agency SCS Plan, 2035
Butte County Association of Governments	in preplanning for RTP/SCS; will kick off project in July 2014 and complete in December 2016	+1%	-2%
Fresno Council of Governments	about to select a preferred scenario for SCS. The final adoption for RTP/SCS will be June 2014.	-10%	SCS not adopted
Kern Council of Governments	expected adoption of RTP/SCS in June 2014	-10%	SCS not adopted
Metropolitan Transportation Commission	all final approvals for RTP/SCS are in; final printed glossy by December 2013	-15%	-16.2%
San Diego Association of Governments	adopted last RTP/SCS in October 2011; started next RTP/SCS, expected completion in 2015	-13%	-13%
San Joaquin Council of Governments	in public process for RTP/SCS; expected completion in 2014	-10%	SCS not adopted
Santa Barbara County Association of Governments	adopted RTP/SCS in August 2013	0%	-15.4%
Shasta Regional Transportation Agency	50% complete with RTP/SCS; expected to complete end-2014	0%	SCS not adopted
Southern California Association of Governments	adopted RTP/SCS in June 2013	-13%	-16%
Stanislaus Council of Governments	policy board has selected preferred scenario of RTP/SCS; agency is developing document narrative	-10%	SCS not adopted
Tahoe Regional Planning Agency/Tahoe Metropolitan Planning Organization	adopted RTP/SCS at the end of 2012	-5%	-7%

All six MPOs that recently adopted their SCS either met or exceeded their targets. Four of the five MPOs that are still developing their SCS plans expect to meet or exceed their targets when the document is adopted.

The majority of MPO respondents considered their targets to be reasonable. One expert expressed frustration with CARB's GHG target-setting process.

A subject from another MPO commented that a particular aspect of CARB's GHG accounting methodology – namely, that MPOs don't have to factor in through-travel in their GHG estimates – helped the MPO to exceed CARB-assigned targets. This is because the proportion of VMT from through-trips – trips that have an origin and a destination outside the region – is expected to increase in the future for that MPO. Many, though not all, agencies indicated that there were significant challenges or barriers to meeting their GHG targets. Three MPOs pointed to a lack of funding to implement strategies as a key barrier. Other barriers appear to be unique to each MPO region. For example:

- One MPO expert explained that a critical barrier is the large expected population growth in the region, coupled with the uncertainty about where the new people will live and work – and whether housing will be affordable enough to support an optimal jobs-housing balance.
- Another subject said that meeting the GHG targets depends heavily on the implementation of a major transit project in the region. Local political dynamics and funding concerns currently threaten the successful completion of that project.
- A respondent from a large urban region said that because the agency's transportation planning efforts include other goals besides GHG reduction, some projects and strategies could increase GHG emissions and ultimately cancel out GHG reductions from other projects. This individual provided the following example to illustrate: A regional express lane network can provide drivers with alternatives to congested roads, but it can make it more difficult to achieve GHG targets because it involves road expansion.
- One respondent from a small urban MPO pointed out that there aren't as many opportunities in small regions to reduce transportation-related GHG emissions as in large urban areas. This is partly because smaller regions are less able to implement the types of strategies that provide the largest proportions of GHG reductions, such as high-frequency transit systems, HOV and toll lanes, and congestion pricing.
- A respondent from a large urban region commented that because the region is mostly "built out" – and urban growth boundaries and open space protections

limit further growth – most of the agency's infrastructure investments must focus on maintaining the existing transportation system. That in turn leaves very limited funds to implement new infrastructure projects that can reduce GHG emissions.
- A respondent from a large urban MPO indicated that a major challenge was providing sufficient technical assistance to the local jurisdictions to update their general plans and associated zoning codes.
- An expert from a mixed rural-urban region cited rural development as a barrier to GHG reduction, particularly because many of the region's GHG reduction strategies are designed for large urban regions.

3.3.3 AGENCY PLANNING PROCESSES

Selection/Prioritization of Strategies: MPOs

There were clear themes among the MPOs regarding their processes to consider, prioritize, and select GHG reduction strategies for their RTP/SCS documents. The most commonly cited approaches to strategy selection were collaborating with local jurisdictions; modeling of strategies and scenarios to assess their GHG benefits; conducting public and stakeholder engagement and outreach; and evaluating the cost of strategies and the availability of funding:

- Five MPOs said that as part of the strategy selection process, they used research and modeling to assess the GHG reduction benefits of strategies. Some of these agencies said that based on this assessment, they removed lower-performing projects from their strategy portfolios. One respondent said that the MPO initially evaluates the data available for a given strategy and determines if it can be modeled. If the strategy can't be modeled, the agency looks for research to support assumptions regarding potential GHG reductions.
- A respondent from a small rural MPO said that in addition to modeling the potential GHG reductions from strategies under consideration, the agency also must evaluate and measure limiting factors to determine if implementation of a given strategy is realistic. The expert offered the following example: Infill and redevelopment in core areas may show promising GHG reduction benefits, but there may be infrastructure capacity and transportation system limitations that restrict its implementation.

- Three MPOs discussed how they created alternative scenarios – in other words, combinations of transportation investments and land use patterns – and modeled them to assess their GHG reduction potential.
- Experts from five MPOs said that the strategy selection process involves working closely with local agencies – such as planning departments – and considering the projects that they are already developing and/or implementing. In some cases, the experts stated that this means working with committees comprised of local jurisdiction officials, and considering and incorporating the GHG reduction components of general plan updates. One MPO said its advisory committee was also comprised of other non-public local organizations, such as the rail commission, a building industry association, and an environmental organization.
- One MPO made the point that its Board of Directors, which is comprised of elected officials of local jurisdictions, must sign off on the RTP/SCS program, and that leadership impacts the selection of strategies. Board members have a variety of decision criteria, and GHG reduction is just one of these criteria.
- Four MPOs said that there was a public outreach and stakeholder consultation process to gather input on strategies and scenarios.
- Three MPOs discussed cost constraints: because the RTP/SCS must be fiscally constrained, a key focus was evaluating which projects were doable with available revenues. One of these MPOs said that it broke up its project list into projects that the agency can pay for and projects that it currently cannot afford. A respondent from a fourth MPO made the point that cost is a particularly significant factor for smaller MPOs because they tend to focus on a much smaller number of projects at any one time by necessity due to limited funds. As a result, cost constraints for small agencies can mean completely shifting course in strategy selection, as opposed to adjusting a broad array of projects for larger MPOs.
- A respondent from a large urban MPO described strategy selection as a multi-phase process. First, there was a GHG reduction assessment for different scenarios. Second, once the agency chose a preferred scenario, it conducted performance assessments for projects, which evaluated their cost-effectiveness and the extent to which they supported the GHG targets. Based on this assessment, some low-performing projects were subsequently removed from the plan. At this point, there was still a gap in meeting the GHG targets, so in a final phase, the agency expanded its suite of climate initiatives to fill the gap.

There were two MPOs that discussed approaches to strategy selection that were not mentioned by any other agencies:

- One rural MPO said that it mainly focuses on transit, bicycle, and pedestrian projects because its organizational mandate prohibits expansion of roadway capacity.
- One respondent said that the MPO conducted a series of studies that evaluated categories of strategies, and used the results to determine the most implementable strategies – and those in turn were incorporated into the RTP/SCS.
- A respondent from one MPO said that its region has successful programs already in place – such as rideshare and vanpool programs – and their success was a key factor in selecting them for inclusion in the SCS.

Selection/Prioritization of Strategies: RTPAs

In one sense, the RTPAs have a similar strategy selection process for their RTP documents. One respondent emphasized the importance of gathering public input and working with local agencies to develop a portfolio of strategies. But beyond that, the three RTPAs demonstrated quite different priorities in their strategy selection process. In particular, GHG reduction was a much lower priority:

- One RTPA respondent said the main goal in selecting strategies for the RTP is not air quality, but rather to improve services for residents and make communities more livable.
- A respondent from another RTPA planned to incorporate GHG reduction elements into the agency's RTP at the outset of the process. But ultimately inclusion of GHG had to be "put on the backburner" due to lack of staff time – and the need to incorporate the required elements into the RTP and complete the document on schedule.
- A respondent from an RTPA located within an MPO region said it relies on that MPO to provide the GHG reduction modeling that is needed to prioritize strategies for its RTP.

3.3.4 GHG EMISSIONS CALCULATIONS

Baseline calculations

To determine baseline year (2005) carbon dioxide emissions for their RTP/SCS documents, most MPOs said that they used their agency's transportation model and/or

CARB's Emission Inventory/Emission Factors (EMFAC) model, in a modeling protocol approved by CARB. These protocols typically involve using models to develop VMT estimates for vehicle classes prescribed under SB 375, which in turn are used to calculate GHG baselines.

Some MPOs provided additional details about the types of data and information that were input into the models, such as population and employment growth data, data from aerial photographs and other land use data, information from local general plans and information about large planned development projects.

One agency described a specific protocol. It first ran its traffic model for 2010 and compared the VMT result to data on actual vehicle counts in 2010. It then calculated a ratio between the model output and the actual count. Next, it re-ran the traffic model for 2005, and applied the calculated ratio to the result to yield base year 2005 VMT.

Approach to counting transportation emissions

All the MPOs said they counted the GHG emissions from the vehicle classes – automobiles and light trucks – prescribed under the SB 375 mandate. All indicated they followed a statewide emissions attribution methodology determined by CARB. Many MPOs added that they worked on their methodology in close consultation with CARB. A few noted that the methodology involved the use of CARB's EMFAC model. One respondent said that in addition to the statewide standard methodology, the MPO used an additional standard methodology developed by an interagency consultation group for the 8-County San Joaquin Valley region.

Because the RTPAs are not required to reduce GHG emissions under SB 375, they did not model any baseline or forecasted GHG emissions.

Technical uncertainties with GHG modeling

While two MPOs indicated there were no major technical uncertainties with modeling GHG reductions, most respondents noted significant uncertainties. For example:

- Two smaller MPOs said that the biggest uncertainty is how to assign responsibility for interregional trips, which may include through-trips or trips that begin or end in the region. One respondent made the point that the Statewide Travel Demand Model used to calculate interregional trips is insufficient. This individual added that this is a critical issue for smaller regions, where interregional travel can often account for a high proportion of overall travel in a region – and thus result in large changes in per capita GHG emissions. The second respondent expressed hope that the updated Statewide Travel Demand Model, which is supposed to be completed in April 2014, will help standardize the assignment of these trips between regions.
- A small MPO pointed specifically to uncertainty regarding visitation to the region – interregional travel from outside the region to inside the region. This type of interregional travel depends on hotel/motel occupancies, which are extremely difficult to forecast.
- Two smaller MPOs said that the small regions do not have as large of a sample of transportation data as large regions. In particular, they pointed to the California Household Travel Survey, which Caltrans conducts every ten years to gather data about the travel behavior of households across the state. While this data can be input into regional travel models as a base to forecast future travel behavior – and GHG emissions – one expert said that small regions only have 100-150 samples from this survey, while large regions have thousands of samples. As a result, there is statistical uncertainty for the small regions in applying their small samples to estimate the travel behavior and emissions of larger populations.
- Two large MPOs said that a key uncertainty with transportation modeling is changing travel behaviors. Such models are based on historic travel behaviors, but travel preferences change over time. For example, younger generations may be more inclined to live in urban areas and take transit than older generations.
- Two MPOs discussed uncertainty regarding forecasts on where future development will occur. A third MPO expert said that its land-use model is limited by a lack of accuracy with regards to local land uses and doesn't consider land values and income level – two key factors in location decisions. This respondent said that a better land use model would result in a "major improvement in our modeling capacity."

- Two MPOs pointed to uncertainty about the future state of the economy, which impacts traffic levels and land use projections.
- One respondent from a small MPO noted a lack of data on fuel costs. The MPO initially included a forecasted assumption for state fuel cost in its modeling that some of the large MPOs had developed and agreed on. When that assumption was input, however, it more than tripled the GHG reductions from the MPO's planning document. The respondent explained that because such an assumption marginalized the impact of the MPO's land use strategies, the agency decided not to include the fuel cost in its modeling.
- One respondent cited uncertainty in estimating GHG reductions due to the interactions between strategies, even if estimating VMT reductions from individual strategies is straightforward. The expert said that this factor could make the MPO's reduction estimates conservative.

Respondents discussed several additional data/information gaps that, if addressed, could help improve their GHG reduction plans. These data gaps include:

- information on population forecasts;
- population data showing number of people living within a certain radius of transit hubs;
- jobs growth forecast;
- the future penetration of fuel-efficient vehicles;
- accurate VMT data – in particular, data that indicates how much of a region's VMT is interregional and how much is intraregional;
- trip counts for non-motorized and motorized vehicles;
- up-to-date and locally relevant information on goods movement;
- "rule of thumb" assumptions for expected GHG benefits of off-model strategies that are applicable to rural regions;
- better tools to forecast economic activity, since that has a huge impact on travel;
- data and modeling on health impacts of transportation, and;
- a version of EMFAC that forecasts further out than 2035.

Strategies that could not be modeled

Most MPOs said they had strategies that didn't fit into their modeling processes, and they had to use off-model GHG reduction estimates for these strategies. There were, however, two MPOs that said they were able to model all of their strategies. One of these MPOs added that it wouldn't even consider strategies that could not be modeled. This respondent acknowledged that there are some CARB-accepted "rule of thumb" assumptions for expected GHG benefits for strategies that could not be modeled, but questioned whether these assumptions could be accurately applied to small MPOs. Most MPOs said that Caltrans could contact them for further technical details. Following are some examples of strategies that the MPOs could not model and explanations of how they handled the GHG reduction estimates:

- A large urban MPO said that its modeled strategies accounted for 99% of the budget of the RTP/SCS. Only eight climate programs – including strategies such as an employer commuter program, carsharing, vanpool incentives, smart driving program, regional electric charger network, and vehicle buyback and plug-in programs – were evaluated off model. Each of these programs was evaluated differently depending on the information available for similar projects. The MPO worked closely with CARB on the assumptions of these off model GHG reduction calculations.
- A medium sized MPO said that it did not model passenger rail service and transportation demand management strategies (carpool, vanpool, ridesharing). This respondent said the agency used a post-processing approach, but was unable provide details during the interview.
- A small rural MPO modeled most of its strategies. There were a few off-model strategies including signal synchronization, transportation system improvements (e.g., regional bus services), and fuel efficiency. For the regional bus service strategy, the MPO based GHG reductions on a transit study that it had conducted. The respondent acknowledged a key uncertainty of this particular off- model estimate – how future land use changes in surrounding regions may affect ridership of that service.
- Two mixed rural-urban MPOs said they have some strategies that they cannot model, and in those cases they use off model tools in "Moving Cooler," a publication from Cambridge Systematics containing data tables to help estimate GHG emissions reductions for various strategies. One of these MPOs said that its off-model strategies include bike lanes, sidewalks, and carpools. The other agency said it could not model its vanpool program because its model does not recognize any commute trips with more than three people. One respondent added that a great deal of the data on strategies in the Moving Cooler report focuses on large metropolitan areas, limiting its applicability to smaller, more rural regions.

- A large urban MPO said it was unable to model a few strategies, including electric vehicle parking and “complete communities” (i.e., mixed-use districts in strategic growth areas with housing, employment, retail, and services located in close proximity to each other). With electric vehicle parking, the MPO did not estimate the GHG reductions off-model due to concerns about overestimating them. The respondent said the agency has better data now and will be able to incorporate the GHG reductions associated with this strategy in the next RTP.
- A large urban MPO said it could not model bicycle network facilities, pedestrian network facilities, vanpools, safe routes to schools, carpools, and buspools. For these strategies, the agency had to assume an emissions reduction factor. However, the modeler decided not to attribute emissions reductions to each individual strategy due to concerns that there were significant interactions among them.

3.3.5 POLITICAL AND SOCIAL OUTREACH

There were several strong themes in how the agencies – both MPOs and RTPAs – achieve political and social acceptance for their plans. Most use some form of public/stakeholder outreach. Most also cited approaches for winning the support of local jurisdictions, including regular meetings with elected officials, collaboration with local agencies or committees comprised of local officials, and sourcing strategies from local general plans and other local agencies. Nearly all MPOs and RTPAs said that their plans had strong support from the public and elected officials by the end of their plan development cycles. Only a few agencies said that they included or excluded strategies due to social or political influence or resistance. Two agencies said that they excluded pricing strategies because of a lack of political acceptability, and one expanded its bicycle and transit initiatives due to social/political factors. Following are more specific responses from the agencies on this topic:

- An expert from a large urban MPO said the big themes in its plan – investing in transit, cultivating focused growth near transit, preserving open space, and prioritizing maintenance of existing transportation infrastructure rather than building new systems – have been the focus of the agency for more than a decade and already have strong public support. Additionally, the transportation investment strategy in particular had local support because most of the transportation projects in the MPO's plan are selected and prioritized by county-level congestion management agencies. The plan won near unanimous approval from the agency's board, which is made up of elected local officials. Nevertheless, while a poll late in the RTP/SCS development process revealed widespread public support for the overarching strategy in the document, there was a vocal minority of small towns and cities opposed to the regional housing allocations in the plan. Also, some elected officials from larger jurisdictions expressed concern about displacement pressures due to infill development strategies. These concerns led to additional protections against displacement in the plan. The only strategy not included due to political/social resistance was a VMT tax.

- A mixed rural-urban MPO gathered input on its strategies and scenarios through a series of public workshops. The respondent said there was general support because the plan addressed citizens' major concerns — long commute trips and the lack of affordable housing. The MPO also had monthly meetings with local public works and planning officials, who provided "nuts and bolts" input on the transportation projects and land use assumptions of the plan. For instance, planning departments provided their perspectives on what future land use changes were likely to happen, while public works departments offered input on their priorities for transportation investments. There was also strong support for the plan among most of the elected officials on the MPO's board, though there were a few officials who did not support the plan due to concerns that the land use elements of the plan might encroach on local land use authority. No strategies were included in the plan due to social or political influence. One strategy – tolls and pricing – was excluded due to lack of social/political acceptance.
- A small rural MPO said that the strategies in its RTP/SCS have been shaped by input received through many years of public outreach. For instance, the public in the region has continually asked for better transit and bike trails. For the most recently adopted update of the RTP/SCS, the agency asked for feedback on its list of strategies through public workshops, and there was broad support in those forum. No strategies were removed due to political resistance.
- A mixed rural-urban MPO conducted a public outreach program that gathered input from 5,000 people. This included phone surveys and online interactive feedback activities. The MPO also met with local elected officials to explain the strategies and how they were developed.

- A respondent from a medium-size mixed rural-urban MPO said the agency conducted two rounds of public outreach – one to gauge citizen support of the strategies and a second to gauge response to the scenarios and performance measures, though the number of people participating in these sessions was small compared to the overall regional population. There were stakeholders that strongly supported more aggressive and less aggressive scenarios than the scenario eventually recommended by the MPO and its advisory committee. The elected officials on the MPO's board had a similar split of opinions between the more and less aggressive scenarios. The respondent said that the middle scenario was chosen to satisfy both sides of the table.
- A mixed rural/urban MPO created an RTP/SCS steering committee comprised of local agencies that will ultimately implement the strategies in the plan. The MPO worked collaboratively with this committee to develop the strategies in the plan over two and a half years. Additionally, the MPO conducted presentations to the public and other forms of public outreach. No strategies were excluded from the plan due to political or social factors.
- A large urban MPO said it went through a two-year public process for outreach, education, and input for the RTP/SCS. This included working with stakeholder groups and policy committees. The MPO included a much more substantial bike network and more transit initiatives than in prior plans as a result of political and social influence. Pricing strategies – including roadway and parking pricing – were not included in the document because there was not enough political acceptance among the MPO's board members. One key unresolved issue with parking pricing was determining which agency has authority to impose such a strategy.
- One respondent from a mixed rural-urban MPO said that the agency employed a bottom-up approach in its RTP/SCS development that involved incorporating the new general plans of the jurisdictions, which had already gone through an extensive public vetting process. No strategies in the MPO's plan were included or excluded due to social or political factors.
- An expert from a rural MPO said that the focus when developing strategies has been on encouraging and reinforcing good practices, not imposing unwanted strategies. As a key part of its strategy selection process, the MPO works with local agencies to select strategic growth areas around which to focus its GHG reduction strategies. These areas reflect existing urban centers and corridors where local general plans permit such development and where there is

demonstrated community support and acceptance for more urban land use patterns (based on new business licenses).

- A medium size MPO said that it conducted a series of workshops with the public and interest groups to educate them about the plan and gather input. The MPO also had monthly meetings with elected officials to educate them about the plan, get feedback, and offer an opportunity to answer their questions in a non-public setting. After the public workshops to review the MPO's three modeled scenarios, a coalition of interest groups proposed a fourth scenario because they didn't like the original three. The MPO responded by modeling the fourth scenario for the coalition, but there was not enough time in the RTP/SCS development schedule to take the four scenarios back to the public for another review round.
- An RTPA said that it gauged the response to its draft RTP from its three standing committees: one comprised of transit operators; another comprised of social service transportation providers and users, and agencies representing the elderly, disabled, and economically disadvantaged citizens; and a technical advisory committee made up of local jurisdiction public works directors and Indian tribes. The respondent said that of the three committees, the technical advisory committee has the most influence with the RTPA's board since its members are implementing the roadway and transit projects. In the current process, no one asked to add or remove strategies.
- A large urban MPO conducted an extensive outreach to the public, elected officials, and a range of stakeholder groups including business, public health, and environmental justice. At the outset of the process, there were divided opinions among the elected officials, but by the end of the process there was unanimous support. No strategies were excluded or included due to social or political influence or resistance, though one included strategy – a VMT fee that will phase in over time – initially raised concerns.
- An RTPA said it conducted an extensive public outreach program, which is particularly important in its region because there is a very vocal conservative population. No strategies were included or excluded due to social or political influence. The plan must be approved by a commission in the RTPA composed of elected officials. Once there is support from the commission, it easily garners support from the local jurisdictions.
- Two respondents – one from a rural MPO and another from an RTPA – said that to be politically and socially acceptable, strategies in their plans must have multiple benefits besides GHG reduction. The MPO said that these other benefits include quality of life, congestion relief, and environmental protection, while the

RTPA cited community benefits like walkability and additional transportation options for people without personal vehicles. By taking such an approach, the plan will more likely get support from elected officials and the public.

- A respondent from a small district said that in order to get the agency's board to approve a measure that has GHG reduction benefits, the agency sometimes has to promote the measure as a "lesser of two evils" – in other words, explain that if the district doesn't adopt the measure, the federal or state government will step in. The respondent provided the following example: There was a controversial proposal several years ago to impose emission mitigation fees on new development projects. Under this proposal, the fees would be used to fund projects that mitigate the VMT increase due to the development. To convince the agency's board to accept the proposal, the respondent made the argument that the district was close to becoming a non-attainment area for federal ozone standards – and that crossing that threshold would mean additional federal oversight in the district.

3.3.6 INTERREGIONAL STRATEGIES

The MPOs and RTPAs all indicated that they were including interregional GHG reduction strategies in their plans, though in varying degrees. Several described interregional strategies as a minor component of their overall planning, while others listed a significant number of strategies. Several strategies are being employed by multiple agencies, including:

- land-use/density approaches: 6 agencies
- some form of rail (not including high-speed rail): 5 agencies
- interregional transit or bus: 5 agencies
- high-speed rail: 4 agencies
- carpools, vanpools, and other transportation demand management strategies: 3 agencies
- ridesharing: 2 agencies
- jobs-housing balance: 2 agencies
- traveler information/message signs: 2 agencies

Most agencies had a mix of strategies that were modeled and strategies that were evaluated off-model. Most respondents were unable to provide elasticities during the interview, but several said that their agencies' technical staff may be able to provide Caltrans with further information about modeling and elasticities. Some agencies discussed their inability to accurately measure interregional GHG emissions due to the lack of an acceptable statewide model, while others said that their model was equipped to measure interregional emissions. Below is a description of each agency's portfolio of interregional strategies and their approaches to estimating interregional GHG emissions reductions:

- A mixed rural-urban MPO said that it is incorporating the interregional strategy of high-speed rail. It is working with a consultant to model GHG emissions impacts. However, the respondent said that these results will not impact the GHG numbers in its RTP/SCS because high-speed rail is primarily interregional through-trips. The expert made the point that per CARB recommendations, the agency should not include interregional travel numbers in either baseline GHG figures or forecasted GHG reductions because the state travel model cannot currently handle these estimations. The respondent said that the agency just evaluates local trips and portions of interregional trips that happen within the region.
- A large urban MPO mentioned three interregional strategies: a proposal to double-track the entire coastal rail corridor (for both people and goods); a proposal to alleviate congestion and reduce truck idling; and land use strategies to boost density and housing capacity to reduce the trend of residents moving outside the region and commuting in for jobs. These strategies were modeled.
- A mixed rural-urban MPO is including the following interregional strategies in its RTP/SCS: interregional rail service extensions; increased emphasis on all transit, including interregional transit; increased emphasis on transportation demand management programs (carpools, vanpools); increased urban density; focus on jobs/housing balance; a congestion management program (i.e., to identify and alleviate bottlenecks); and a significant decrease in roadway spending coupled with a significant increase in transit spending. All of these strategies were modeled except for the rail service and transportation demand management. The GHG reductions of the modeled strategies were estimated through the agency's transportation model. The respondent said that it has a "vastly improved" three-county transportation model that measures trips through and within a region that includes the MPO's coverage area as well as two neighboring counties.

- An RTPA said it had two key interregional strategies: changeable message signs on freeways with information on road conditions and accidents; and major truck stops to encourage trucks to park rather than idle. The agency is not modeling any interregional strategies.
- A rural MPO said that its key interregional strategies are interregional transit; ridesharing; land use strategies that transfer development (and thus residents) into town centers. The agency estimated the GHG reductions of interregional transit through a recent transit study it conducted. For ridesharing, the agency evaluated studies with reduction estimates for peer regions, took an average of those numbers, and used the conservative end of the range. The agency had also conducted a license plate survey of the region's entry points to gain a better understanding of where vehicles were traveling from. This data helped to boost the agency's confidence in its estimates.
- A mixed rural-urban MPO said that its only interregional strategy was a better jobs-housing balance through increased regional employment. The region currently has a high unemployment rate, and many residents commute out of the region into an adjacent urban center. The MPO didn't model how changes in jobs-housing balance impact GHG reductions, and the agency doesn't have elasticities for this strategy. It used the same jobs-housing balance in all of its scenarios.
- An RTPA pointed to two interregional strategies that it is promoting: ridesharing and expanding an interregional non-motorized network. The respondent also described a multi-county study that it is involved in that evaluates the corridors that connect major urban centers to other smaller recreation destinations outside the region. The participating counties are considering traveler information strategies that have potential to reduce interregional GHG emissions.
- An MPO in a remote rural region said that it only has minor strategies to address interregional travel, including rail, a regional airport, and intercity bus. The respondent acknowledged that the MPO had no major region-wide strategy that will result in a significant change in interregional VMT, and it does not plan to model the emissions reductions from these strategies due to their insignificant nature. The respondent explained that the only feasible way for the MPO to achieve a critical mass of GHG reduction – and meet its targets – was to focus its efforts on small urban core areas where it can layer multiple strategies like transit, density, and design. Without such an urban focus in its plan, the respondent said it would be impossible to meet its GHG targets.
- A mixed rural-urban MPO said that its plan seeks to reduce — and its transportation model is able to account for — the GHG emissions of commuter

trips that begin or end in the region, but not external-to-external trips. It is addressing these commuter trips through the core strategies in its plan: transit-oriented development and infill approach to future growth. The agency has a high level of confidence in its estimates, but the respondent acknowledged that its assumed allocation of growth in the evaluation is a major uncertainty. The respondent had no elasticities to provide.

- A respondent from a large urban MPO discussed how a key goal of the agency's RTP/SCS — and more broadly, of SB 375 — is to reduce interregional travel by encouraging more people to not commute between regions. The respondent acknowledged that intercity rail is a key interregional transportation system in terms of GHG reduction potential, but said it was not included in the agency's RTP/SCS because it was not cost-effective enough. Instead, the agency is directing its investments to the core of the region, rather than for interregional systems situated at the region's periphery. However, this MPO is supporting the high-speed rail system among its strategies. The agency also has a set of climate programs that could impact interregional GHG emissions, including employer-provided subsidies, carsharing, vanpools, clean vehicles feebate program, vehicle buyback, electric vehicle charging, and smart driving program. The GHG emissions reductions of the climate programs were forecasted off-model; each was evaluated differently depending on information available about similar projects. This MPO said that its transportation model accounts for trips between regions, and that there is coordination with neighboring MPOs on these traffic flows.
- A mixed rural-urban MPO said that it is including the following interregional strategies in its RTP/SCS: commuter rail; incentives for employer-based vanpools; and interregional bus. GHG reductions from commuter rail and interregional bus were estimated within its transportation model. Because the model does not recognize any vehicle commute trips with more than three people, the model could not be used to forecast GHG reductions from the vanpool program. The agency is considering using the Moving Cooler report for an off-model estimate of its vanpool program. The respondent said the agency was confident in its modeled estimates but less confident in its off-model estimates, because the elasticities may be more appropriate for more dense urban areas.
- A mixed rural-urban MPO said that it is attempting to incorporate high-speed rail into its modeling, but added that there is insufficient ridership forecast data and lack of cooperation from state agencies needed to make good estimates. The expert said the MPO can estimate interregional GHG reductions — in particular

trips beginning or ending in the region — in its transportation model. This respondent noted that MPOs throughout the state may not have consistent estimates — a problem that could be addressed by a statewide model. This agency is not attempting to estimate interregional GHG reductions off-model.

- A large urban MPO said the key interregional strategy in its plan is building the supportive interregional rail system to accompany the statewide high-speed rail. The respondent did not know the technical details of the modeling of this strategy. The expert did know that the MPO claimed very little GHG reductions from this strategy due to the inherent uncertainties of high-speed rail.
- An RTPA said that it has a strategy to support coordination of interregional public transit that connects with county level public transit services. The agency is not modeling this strategy. It has not made an off-model estimate of interregional GHG reduction, but it may do that in the next RTP update.

Interregional strategies that Caltrans could lead

Most agencies offered specific suggestions for interregional GHG reduction strategies where Caltrans could assume a leadership role; only three had no suggestions. In almost every case, each agency offered a unique recommendation for how Caltrans could be a leader in the interregional realm. The one clear exception was the suggestion, made by five agencies, that Caltrans should take more leadership on completing the Statewide Travel Demand Model, so that agencies can make more accurate estimates of interregional travel-related GHG emissions. Here are the suggestions from the agencies:

- A mixed rural-urban MPO strongly recommended (several times in the interview) that Caltrans complete the Statewide Travel Demand Model so agencies can use it to quantify interregional trips. The respondent said that such a model is a vital part of conducting accurate interregional trip modeling. The expert added that Caltrans' strategy of continued freeway expansion works against regional transit development efforts because it maintains freeways as a more attractive option relative to transit. "You need a little congestion so people would consider transit," the respondent said.
- A large urban MPO said that an enhanced Statewide Travel Demand Model would help the agency make better estimates of the GHG benefits of interregional rail and statewide high-speed rail in the next RTP cycle.

- An RTPA suggested that Caltrans help implement more park-and-ride lots at highway system interchanges, and assist in promoting ridesharing opportunities at the park-and-ride lots.
- A mixed rural-urban MPO said that Caltrans should be more focused on interregional travel (both passenger vehicle and freight) on Highway 101 -- particularly long trips that go to and from the Los Angeles and San Francisco Bay Area regions. The respondent suggested that Caltrans could invest in targeted capacity enhancements along the 101 corridor, such as widening the roadway at bottlenecks.
- An RTPA suggested that Caltrans take a leadership role to improve traveler information provided to tourists and other travelers making interregional trips between urban areas and rural recreation hubs. As an example, the expert explained that if there's a landslide on a rural road in the middle of the winter, several hundred vehicles could be idling for hours — a situation that could be alleviated if travelers were provided information on alternative routes and alternative recreation options. The respondent thought this strategy could help reduce the tourist/recreation-related congestion that is not as widely recognized as a problem compared to daily commute congestion.
- A rural MPO suggested that at the district level Caltrans can help with intelligent transportation systems on state routes and I-5, including active ITS and passive monitoring. At a state level, the respondent said, Caltrans can help develop the Statewide Travel Demand Model. This respondent noted a need for more funding from Caltrans for project implementation to achieve the SB 375 targets.
- A mixed rural-urban MPO suggested that Caltrans complete the Statewide Travel Demand Model to improve accuracy of interregional travel numbers. It also recommended that Caltrans provide better funding for the California Household Travel Survey.
- A respondent from a small district suggested that Caltrans take leadership on providing more turnouts on a highway in the region that is heavily used for agricultural traffic.
- An MPO suggested that Caltrans take more leadership on improving Amtrak, and evaluate the possibility of shuttle service connections between the Bay Area, Sacramento, and recreation destinations.
- An RTPA recommended that Caltrans provide funding to Greyhound for a more robust system. The respondent also suggested that Caltrans more closely evaluate the GHG impacts of air travel in California relative to other transportation modes.

- A respondent from a small district said that there is a perception in the region that the state has less interest in helping rural regions fund GHG reduction infrastructure – such as truck stops and EV charging stations – compared to urban regions. He described an example of this economic challenge: The region had a major truck stop that was fully equipped with electrical hook-ups (for anti-idling) that were later dismantled when the truck stop ownership changed.
- An expert from a mixed rural-urban MPO said that the primary uncertainty in modeling interregional travel is that Caltrans' statewide model is unable to accurately calculate the magnitude of this travel. This respondent added that another uncertainty in the current modeling of future interregional travel-related GHG emissions is migration. For instance, the respondent explained that if the Bay Area or Southern California doesn't provide enough housing to serve the growing number of jobs, the housing could spill over into surrounding regions — and commuters could move from the urban areas into those regions, significantly increasing interregional GHG emissions. The respondent said that the current approach to quantifying this migration — the California Department of Finance's trend analysis based on drivers license change forms — is archaic. This expert didn't specifically suggest that Caltrans take leadership on this role, but expressed concern that no state agency was taking a close look at this issue.
- A large urban MPO said that Caltrans should develop new funding sources to discourage long interregional trips. In particular, the respondent suggested that Caltrans consider a state-level VMT fee, which could alleviate congestion along interregional corridors.

3.3.7 GOODS MOVEMENT STRATEGIES

Only eight of the 14 MPOs and RTPAs interviewed said they were including goods movement strategies in their RTPs. The GHG emissions reductions were being modeled for some of these strategies, but not for others. None of these agencies had any elasticities to share for goods movement. Most respondents said that Caltrans could contact their agencies for further technical details about modeling and elasticities.

Six agencies — five MPOs and one RTPA — are not including any goods movement strategies in their RTPs. Two of these agencies — one rural MPO and one RTPA — said they did not include goods movement strategies because there isn't much goods movement through their regions. Two of the MPOs said that they didn't include these strategies because goods movement emissions are not included under the scope of the SB 375 mandate. Two MPOs said that while they are not quantifying the GHG emission reductions from goods movement strategies in their plans, the agencies are still looking at goods movement from a planning perspective. A rural-urban MPO said that the agency is not seeking to restrict goods movement in the region, since goods movement is viewed as an economic benefit and encouraged by the local jurisdictions.

Below are the specific strategies and modeling details provided by the eight agencies with goods movement strategies in their plans:

- A large urban MPO said that it is investing in a major goods movement intermodal terminal with direct connections to the rail network. Other strategies include truck scales and a truck climbing lane on freeways, as well as a port system where ships can plug in to receive electric power. The freeway projects were modeled with the agency's travel model and emissions model, just like other projects in the RTP/SCS. The intermodal terminal and plug-in power for ships were not modeled and not included in the GHG analysis in the plan. Regarding elasticities for goods movement strategies, the respondent said that modeling these strategies is much more complicated than simply plugging in an elasticity value in the model. The respondent added that there was a lesser focus on goods movement in the recent RTP cycle because the SB 375 targets are only for cars and light duty trucks.
- A mixed rural-urban MPO said that its main strategy is to promote more shipping by rail and less shipping by truck. The respondent said that it only models this strategy at the intermodal facility, and not the reduced truck trips to the edge of the region and beyond. The MPO does not have any elasticities for this strategy.
- A large urban MPO said that it is planning port improvements to facilitate goods movement. The strategy is being modeled. The respondent said that the MPO is also collaborating with Caltrans on building a major goods movement corridor.
- An RTPA mentioned two goods movement strategies: a Caltrans project to widen a winding section of a highway to allow larger trucks to pass through (currently big trucks have to offload onto smaller trucks before entering this section); and an

effort to rebuild a harbor for short-sea shipping. The agency is not modeling these strategies and has no elasticities.

- A large urban MPO said its primary strategy is to implement separate truck lanes to more efficiently move goods from ports to outside the region. The respondent explained that a key uncertainty with estimating this strategy's GHG reductions is the evolution of low emissions truck and railroad technology. As a result, the MPO is taking a conservative approach in estimating the GHG benefits. The respondent did not know the technical details of modeling this strategy.
- A mixed rural-urban MPO said that its good movement strategies include coordination of land use and transportation planning, and congestion management. Both are being modeled with the agency's transportation model. The respondent also mentioned that the eight-county San Joaquin Valley region coordinated on an interregional goods movement plan to identify opportunities and constraints to goods movement.
- An RTPA is considering conducting a study on the potential to reduc commercial vehicle VMT by improving capacity of and access to agricultural processing facilities. From conversations with farmers, the respondent has learned that processing facilities in the region are sometimes overloaded, and trucks may have to drive a long way to reach processing facilities with available capacity.
- A rural MPO said that in the near-term it is considering enhancing alternate routes for goods movement travel. There are large regions that are only accessible by one state route that is susceptible to land-slides and weather events. A road closure may require trucks to take a several hundred mile detour and may take years to be repaired. A long-term strategy under consideration — though still considered a "pipe dream" by the respondent — is an intermodal freight terminal for aggregating and distributing wholesale goods. The need for such a facility was outline in a transportation and economic development study for a 16 county region. The study found that there is no convenient way to move goods to market in the region other than by truck. The MPO may try to estimate GHG reductions from the near-term strategy (and possibly other goods movement strategies), but the respondent said that the margin of error in the estimate will be large due to a "severe" lack of data on goods movement, particularly in rural areas. The subject added that this lack of data makes it difficult to develop goods movement strategies.

Goods Movement Strategies that Caltrans should lead

All agencies except two offered a variety of suggestions for goods movement strategies for Caltrans to lead:

- A large urban MPO said that Caltrans could provide more statewide coordination on establishing efficient locations of inland ports to expedite goods movement.
- A rural MPO suggested that Caltrans implement another intermodal goods movement facility along the I-80 rail corridor.
- A mixed rural-urban MPO recommended that Caltrans decrease its focus on expanding freeways while expanding rail usage for goods movement.
- A mixed rural-urban MPO said that Caltrans could take leadership on optimizing efficiency of goods movement across modes throughout the state.
- A small rural MPO said that Caltrans could lead in the maintenance of key interregional goods movement facilities. Caltrans can also play a leadership role in advocating at the federal level for the importance of improving the conditions/reliability of state routes. The respondent explained that federal law focuses federal transportation funds on routes that have a certain percentage of truck travel as their overall value — a criterion that excludes all state routes in the northern part of the state except I-5.
- A mixed rural-urban MPO suggested that the state rail plan should address short-haul rail travel within California, which has significant GHG reduction potential. The expert explained that few agencies are considering the strategy of hauling products to ports for export by rail, since Class 1 railroads refuse to haul distances of less than 700 miles — the length of the state. As a result, potential rail shipments from the Central Valley to the ports and distribution centers go by truck. The state should incentivize a short-haul rail network, or at least encourage a commitment from the Class 1 railroads to haul from central California to the ports.
- An RTPA said that Caltrans could help with two significant needs: implementing an interchange on I-5 that could enhance access to the highway by distribution center and other industrial uses in the area; and adding turn lanes to a two-lane highway in the region that has a great deal of farm equipment traffic.
- A large urban MPO suggested that Caltrans establish state priority goods movement corridors and evaluate ways — such as more flexibility in how funding is allocated — to balance the freight rail network and the highway network.
- An RTPA suggested that Caltrans advocate strongly for higher emissions and fuel efficiency standards for the trucking industry.

3.3.8 ADDITIONAL RECOMMENDATIONS TO CALTRANS ON GHG REDUCTION STRATEGIES

At the end of the interviews, researchers gave interviewees a final opportunity to offer additional recommendations to Caltrans not previously discussed in the conversation. These could include promising GHG reduction strategies that agencies could develop in partnership with Caltrans; other GHG reduction strategies that Caltrans should lead; and any other recommendations to Caltrans as it develops the next update to the California Transportation Plan:

- One large urban MPO and two rural-urban MPOs discussed how Caltrans could help coordinate uniform data sources and modeling platforms across MPOs and state agencies. By saving regions the trouble of having to reinvent the wheel, such coordination could reduce costs and create a more consistent and comparable set of models — and in turn yield better estimates of interregional travel and GHG emissions.
- An RTPA respondent observed that most state transportation money seems to go to road projects and recommended that Caltrans become a more multimodal agency and invest in other types of transportation and land use planning.
- A rural MPO offered three additional recommendations. First, it would like to begin working with Caltrans on interregional transit projects. Second, it would like Caltrans to work with the Sacramento and San Francisco airports to develop shuttle services to recreation destinations. Finally, Caltrans could improve the connections of the Amtrak throughway.
- A large urban MPO said that Caltrans could take a stronger leadership role on investigating future transportation technologies by collaborating with federal agencies that conduct research in this realm, such as the Departments of Energy and Transportation. The respondent recommended that Caltrans could also take the lead on researching the global supply chain.
- A respondent from a small district offered three additional recommendations. First, the respondent made the point that most of the funding under Proposition 1B goes toward the primary goods movement corridor — the Bay Area to Sacramento and Sacramento to San Joaquin and down to Los Angeles — and very little goes to regions north of Sacramento. The respondent said this hinders the

ability of rural regions north of Sacramento to achieve GHG emissions reductions. Second, Caltrans should invest more in electric vehicle charging infrastructure outside of Sacramento on the I-5 corridor, including charging stations at rest areas and charging stations in small town centers. Third, the respondent recommended that Caltrans implement bike paths or trails in the extensive right-of-way along the I-5 corridor to help get recreational riders off of I-5 and provide a further incentive for people to travel by bike. There are parts of the region where I-5 is the only road, so bikers are forced to ride on the I-5 shoulder, which in itself is a disincentive to biking.

- An RTPA said it would like to see Caltrans mark more bike lanes on certain state routes.
- A rural MPO said that Caltrans could work to compile up-to-date, locally relevant data on goods movement.
- A mixed rural-urban MPO said that it would like help from Caltrans in implementing active transportation projects (e.g., biking, walking modes) along state highways.

4. Topic Literature Reviews

The purpose of the literature review was to appraise the state of knowledge and practice regarding a variety of transportation system efficiency and VMT reduction strategies in relation to interregional travel. These topic literature reviews provide a jumping off point for further investigation, indicating promising strategies and pointing to areas where further research or information is necessary. The literature reviews were designed to capture quantitative and qualitative knowledge about the topic area and GHG emission reductions, including uncertainties. The literature reviews note implementation efforts and policy pertaining to the strategies, as well as elasticities and analytical tools when included in the reviewed literature.

Two summary matrices were developed reflecting system efficiency and VMT reduction strategies. The summary matrices distill the topic literature reviews, including qualitative and quantitative summaries of the strategies and GHG emissions impact. In addition, the matrices provide a rating assessment of the interregional impact of the strategy, technical level of confidence in the data, and political acceptability.

Interregional impacts are rated as:

1. High: significant potential to have an effect on GHG emissions
2. Moderate: could have significant impact on GHG emissions depending on the circumstances where the strategy is applied, but may have negligible effect or not be appropriate in other circumstances
3. Low: limited effect on GHG emissions
4. Very Low: not likely to impact GHG emissions

Technical level of confidence are rated as:

1. High: multiple studies in agreement
2. Moderate: few studies, uncertainties in the studies and assumptions
3. Low: limited studies, some discrepancies among studies
4. Very Low: limited or no studies, conflicting results

Social/Political Acceptability is rated as:

1. High: no or very limited public cost, voluntary
2. Moderate: some compulsion, low cost
3. Low: significant cost and time, public/private, various players
4. Very Low: substantial cost, interference with public behavior

The literature rarely provided information specific to interregional impact of a strategy, technical level of confidence or social/political acceptability. Therefore, the rating systems reflect both information from the literature reviews as well as study team expertise and background in transportation. The subjective aspect of the rating system is particularly prominent for strategies that could have a mixed result depending on the circumstances. For example, ramp metering and high occupancy vehicle (HOV) lanes may have a very low GHG reduction impact on interregional roads that are not affected by congestion. On the other hand, the effectiveness of ramp metering or HOV lanes as a strategy to reduce GHG emissions from interregional travel in areas that are affected by congestion, may be much higher and perhaps equivalent to using these strategies in an urban congested region.

4.1 System Efficiency Summary Matrix

The system efficiency matrix (Table 3) includes 22 strategies covering operational efficiency, construction, goods movement, and public education/behavior. The system efficiency matrix is based on the topic literature review conducted by this study team. The topic literature reviews and all references can be found in the following appendices:

Appendix B: Operational Efficiency
Appendix C: Construction
Appendix D: Goods Movement
Appendix E: Public Education/Behavior

Operational Efficiency: Among the operational efficiency topics reviewed, none were found to have an overall high impact on interregional GHG emissions. The impact of many strategies will be variable depending on the conditions that exist in specific locations. Often there will be a greater GHG impact in more congested, higher usage roadways and a lower impact in areas with less traffic. These strategies were given a moderate rating for ability to impact GHG emissions from interregional travel. The following were estimated to have a moderate interregional impact for reducing GHG emissions:

- Incident Management
- Integrated Corridor Management
- Transportation Systems Management: ITS
- Ramp Metering

The following strategies were estimated to have a low or very low interregional GHG impact:

- Air Traffic Ground Operations
- Traffic Signal Optimization

Construction: The two topics reviewed under construction were estimated to have a high potential to reduce GHG emissions from interregional travel because all interregional roadways would be impacted:

- Construction Materials
- Road Surface

Goods Movement: Many goods movement strategies had a high potential to reduce GHG emissions from interregional travel, as a good portion of goods movement is between urban areas:

- Double Stack Network for Rail
- Intermodal Facilities Close to Ports
- Ports and Marine Operations

- Mode Shift to Rail from Truck
- Overweight Load Permits
- Truck Size and Weight Limits
- Truck Stop Electrification
- Weigh in Motion

The following goods movement strategies were estimated to have a moderate or low interregional GHG impact:

- Low Emission Freight Corridors
- Urban Consolidated Centers

<u>Public Education/Behavior:</u> Public education/behavior strategies ranged from high to moderate for impact on interregional GHG emissions:

- Ecodriving for trucks (high)
- Ecodriving for passenger cars (moderate)
- Reduce Speed Limits (moderate)

Table 3: System Efficiency Summary Matrix

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Operational Efficiency (See Appendix B for references and further information)						
Incident Management	Incident management programs are utilized by many departments of transportation worldwide to identify, analyze, and correct minor and major traffic incidents to help mitigate traffic backups, as well as increase public safety. Incident management programs generally include three primary functions: traffic surveillance (the process of detecting and verifying traffic incidents), clearance (coordinating emergency response teams to the site of the incident), and traveler information (notifying motorists of the incident to provide time to select an alternative route). Recent developments in the field of Intelligent Transportation Systems (ITS) have allowed some incident management programs to utilize radar, lasers, and video surveillance to more effectively detect and respond to traffic, Because incident management can reduce traffic delay and congestion, it may also reduce fuel consumption and resulting GHG emissions.	The Federal Highway Administration found that studies of the GHG benefits conducted throughout the U.S. show varying impacts on GHG emissions reduction per incident, ranging from 2 metric tons of CO_2 to 23 metric tons of CO_2 compared to situations with no incident management. Florida's Road Ranger program, part of the SMART (Systems Management for Advanced Roadway Technologies) ITS deployments package, was estimated to save approximately 1.8 million gallons of gasoline and 14,000 metric tons of CO_2 emissions annually.	3. Moderate: Traffic incident clearance programs can impact interregional travel, with greater impact in more congested areas.	Not found in literature reviewed	2. Moderate: Estimates of traffic delay reductions depend on a number of prevailing traffic conditions such as: traffic volume, incident topology, and roadway characteristics in the region where services are provided. Because these conditions can vary significantly from region to region, it is difficult to generalize results across different programs. In addition, data from these programs do not explicitly account for induced demand, which may reduce or negate the fuel and emission reduction benefits of incident management programs.	1. High: Incident management programs are generally acceptable given the time and fuel savings benefits that they offer to motorists. Although generally accepted, programs may require inter-agency coordination across jurisdictions and transportation facilities to implement the programs in full.
Integrated Corridor Management	Integrated corridor management (ICM) is a strategy to maximize the effectiveness of intelligent transportation systems (ITS) to mitigate congestion along the most heavily trafficked transportation corridors. More specifically, ICM refers to the coordination of network and control systems along multiple transportation corridors to create a more interconnected system capable of effectively managing traffic and system demand using communication and sensory technologies. Through this integration, ICM seeks to optimize the use of available infrastructure by directing travelers to underutilized capacity within the transportation corridor.	One study estimated annual fuel and emissions savings for the San Diego, Dallas and Minneapolis ICM projects. The report predicted annual fuel savings of 323,000 gallons (San Diego), 981,000 gallons (Dallas), and 17,600 gallons (Minneapolis). This would correlate to approximately 6 million, 17.6 million, and 316,800 lbs of annual CO_2 reductions for the three sites respectively. The report also estimated annual mobile emissions reductions of 3,100 tons (San Diego), 9,400 tons (Dallas), and 175 tons (Minneapolis).	2. Moderate: This strategy is typically implemented where there is a network of roadways and/or mode options as well as some level of congestion. Interregional travels tends to have fewer viable options for alternate routes or modes. However, in certain interregional situations where there are alternative routes and congestion, ICM may be very effective.	Not found in literature reviewed	2. Moderate: The effects of ICM depend on the size of the corridor, the particular ITS technologies utilized, the coordination of such ITS technologies, and the initial level of traffic congestion and underutilized system capacity.	1-4: Because ICM integrates a multitude of ITS technologies, public perceptions of overall ICM deployment will depend on their opinions toward each individual ITS strategy.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Operational Efficiency (See Appendix B for references and further information)						
Transportation Systems Management: ITS	Transportation systems management and operations (TSMO) refers to multimodal transportation strategies to maximize the efficiency, safety, and utility of existing and planned transportation infrastructure, such as traffic incident management, traffic signal coordination, transit signal priority and bus rapid transit, special event management, road weather management, managed lanes, parking management, electronic toll collection and transit smart cards, and traveler information systems. While the primary goal of TSMO is to serve the mobility needs of people and freight and foster economic growth and development, it also has potential to reduce greenhouse gas (GHG) emissions by mitigating congestion, managing excessive speed, and smoothing traffic flow. TSMO strategies are often enabled or supported by intelligent transportation system (ITS) technologies and applications.	Because TSMO encompasses a wide range of strategies, the range of fuel savings and GHG reductions that result from implementing these strategies can vary significantly. A few examples: Modeling studies of coordinated signal control in 5 U.S. localities found reductions in fuel use ranging from no significant change in Seattle, Washington to a 13 percent decline in Syracuse, New York. A simulation study for the San Antonio, Texas, region found that an implementation of travel information systems could decrease annual vehicle fuel consumption by 1.2% to 3%.	2. Moderate: TSMO strategies can have local, regional, or interregional impacts. TMSO encompasses a broad range of strategies. Some will have negligible GHG impact for interregional travel while others will have a greater impact.	One recent study on the GHG impacts of a variety of transportation strategies used elasticities of travel with respect to total vehicle operating cost, which includes travel time, fuel costs, maintenance costs, and other out-of-pocket expenses. The elasticities of -0.4 for short-run and -0.8 for long-run were used for all transportation strategies studied including TSMO strategies.	2. Moderate: The GHG benefits of TSMO vary depending on the area's local fleet composition, existing level of congestion, and existing level of excessive speed travel (which in turn depends on speed limits and enforcement).	1. High: In general, the political acceptance of TSMO is high. The Federal Highway Administration has a funding mechanism for TSMO programs. Also, several state and local agencies have already successfully implemented a variety of TSMO strategies. Most TSMO strategies bode well with the public as they provide perceivable improvements to the public's traveling experience.
Ramp metering	Ramp metering is defined as the process of facilitating traffic flow on freeways by regulating the number of vehicles entering the freeway per interval of time through the use of control devices (most commonly traffic signals) on entrance ramps. The goal is to control the entry of cars onto the freeway in order to ensure proper spacing between vehicles is achieved and to limit the impact of newly merging vehicles on overall highway traffic flow. It is posited that by metering or controlling the flow of traffic onto a freeway, ramp metering devices may serve to reduce overall fuel use and subsequently promote reductions in GHG emissions. However, vehicles idling at the ramp meters may also increase emissions.	The benefits of ramp metering to reduce GHG emissions are variable and uncertain. Some studies report that ramp metering increases CO_2 emissions, primarily because of increased idling at the on-ramp. However, other models and simulations report a net decrease in emissions, primarily from smoother traffic flows. One recent study conducted by a group of South Korean researchers showed an overall decrease in CO_2 emissions as a result of ramp metering. The study showed that while the emissions of vehicles at on-ramps were increased, there was a 7.3% net reduction in overall CO_2 emissions. Another study analyzed the potential traffic alleviation benefits of ramp metering in the San Joaquin valley. The report concluded through simulation that ramp metering would tend to increase mainline vehicle speeds by roughly 5%, and that overall there would be negligible fuel savings and GHG emissions reductions, finding only a 1% improvement.	2. Moderate: Ramp metering is typically implemented in large metropolitan areas at times of day when there is significant congestion. Ramp metering may have similar impact on congested inerregional roadways. Ramp metering will have negligible impact on non-congested roadways and could increase GHG emissions by increasing stop and go traffic at highway entrances where traffic was previously free flowing.	Not found in literature reviewed	3. Low: In general, most studies fail to fully characterize the change in GHG emissions due to ramp metering because of unintended consequences such as hard accelerations and induced demand. Thus the studies may or may not be completely accurate. The literature on the effects of ramp meters varies due in part to the differences in what is accounted for in the studies and simulations; for example some studies include idling at ramps, induced demand, increased traffic on local street networks, or increased speed on highways from improved traffic flow while others do not.	3. Low: The barriers to the implementation of successful ramp metering are the perceived inequities as well as the perceived delay increases. Although it has been shown that ramp metering usually decreases the incidence of traffic congestion on the primary road, the public generally feel that ramp metering leads to greater delay while waiting to enter the primary road. As a result, politicians may be wary to support a ramp metering device because of negative public perceptions. In addition, ramp metering tends to benefit travel times for long distance trips more so than it does for short distance trips. As a result, this inequity could result in some political reservations to instituting the technology.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Operational Efficiency (See Appendix B for references and further information)						
Air Traffic Ground Operations	GHG mitigation strategies come from three major sources: airport operators, aviation, and ground transportation. For airport operators, emissions reductions can be achieved from modernization of power, heating, and cooling systems, design of "smart" energy efficient buildings, modernization of fleet vehicles, driver education on fuel conserving driving techniques, and waste management. In terms of aviation, emissions reductions can be achieved from improved taxiway, terminal, and runway configurations, as well as modernized departure and arrival management systems. For ground transportation, emissions reductions can be achieved from the provision of public transport and rapid transit, educational campaigns to reduce vehicle idling, hotel and rental car agency shuttle bus consolidation, encouragement of alternative fuel or hybrid vehicles, and provision of fuel/power infrastructure for low-emission vehicles.	GHG emission mitigation measures for ground transport at San Francisco International Airport helped mitigate 41,816 tonnes of GHG in 2010, 62,381 tonnes of GHG in 2011, and 69,776 tonnes of GHG in 2012. One study found that ground transport at the Intercontinental Airport of Houston emitted 13,050.98 kg of CO2 within a one-year period in 2002.	3. Low: Ground transport at airports is generally localized to a specific county.	Not found in literature reviewed	3. Low: One study notes that urban transportation planning processes do not adequately provide simulation models to address the unique traffic and emission problems of airports. A simulation model that can best capture the conditions at airports should consider car following behavior, vehicular specific characteristics such as acceleration and deceleration, distribution of speed at which vehicles drive through a terminal, distribution of arrival time at an airport, and distribution of waiting time inside an airport.	3. Low: Unlike in Europe, US jurisdictions have traditionally not prioritized public transportation to airports, making it more difficult to persuade passengers and airport workers to utilize alternatives to single-vehicle occupancy driving to airports.
Traffic Signal Optimization	Proper control and timing of traffic signals can reduce stop-and-go driving, engine idling, and traffic congestion, promoting smoother flowing traffic and reduced GHG emissions. Such signal timing can be achieved with either static or dynamic control. With static operation, traffic signals operate under a fixed time schedule that controls the changeover from green to red lights, whereas dynamically controlled signals utilize real time traffic information to adjust the signal timing.	A study of coordinated traffic signals conducted within the metropolitan area of Phoenix Arizona, along the Scottsdale Road–Rural Road corridor, found that fuel consumption was on average reduced by 1.6 percent over all of the measured intersections. A Parisian study found that an intersection equipped with a real-time adaptive signal control system known as CRONOS, led to a 3-4% reduction in GHG emissions. In 2009, as part of the Clinton Climate Initiative, the City of Portland optimized traffic signal timing at 135 intersections on 16 different city streets. It was concluded that the optimization decreased fuel consumption by 1.75 million gallons of gasoline per year. This fuel savings translates to approximately 15,500 metric tons of CO_2 per year, or roughly 115 metric tons of CO_2 per intersection per year.	4. Very Low: Traffic signal optimization usually is implemented at a local or regional level.	Not found in literature reviewed	3. Low: The benefits of traffic signal optimization depend on a variety of factors, including the previous level of traffic congestion and the approach that was used to coordinate or optimize traffic signal timing. Estimates of reduced fuel consumption and emissions must be interpreted cautiously, because signal optimization may induce demand and reduce potential benefits. Another limitation of signal optimization studies is that estimates of fuel consumption are sometimes too simplified to accurately account for the wide array of vehicles in operation. Because emissions vary greatly between different makes, models, and ages of cars, the results of any model depend greatly on what assumptions have been made.	2. Moderate: Because signal optimization is usually undertaken to mitigate traffic congestion, it is likely to be supported by the public. However, there may be some concern regarding the negative impacts on pedestrian / bike crossings. If signal optimization programs were to lead to longer green lights, there may be fewer opportunities for pedestrians / bikers to cross a given intersection. This may result in a reduction of safety for pedestrians, cyclists, and even drivers.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Construction (See Appendix C for references and further information)						
Construction Materials	Production of cement and asphalt – key materials in pavement – account for significant industrial process-related carbon dioxide (CO_2) emissions. As a result, transportation agencies are beginning to use alternative materials in order to decrease the adverse effects of construction on the environment. The most common forms are the use of fly ash and slag in concrete mixture, the use of warm- or cool-mix asphalt instead of hot-mix asphalt, and the use of recycled materials in pavement and bridge construction.	There are several examples of agencies using alternative construction materials, but few research studies specifically calculate the energy savings and GHG reductions from using these types of construction materials. Moreover, energy savings and emissions reductions from the use of alternative materials vary depending on type of material, percent of recycled content, the scope of project, and other factors. One study estimated that every ton of fly-ash substituted for Portland cement reduces life-cycle CO_2 emissions by almost one ton. Another study reports that using warm-mix asphalt instead of the traditional hot-mix asphalt can reduce energy consumption and CO_2 emissions during the mixing process by 15-35% while half-warm mix and cold-mix asphalts can reduce energy consumption and CO_2 emissions by 50%. In an Australian study, recycled aggregates take 46% less energy (and thus reduce GHG emissions) to produce than new aggregates.	1. High	Not found in literature reviewed	2. Moderate: The type of alternative construction materials used as well as the materials they are replacing can vary the energy use and GHG emissions of the construction. Also, a comprehensive analysis of the reduction should account for life-cycle energy use and GHG emissions from the production of the materials to the transport of the materials to the site to the mixing and using the materials in the construction.	1. High: This strategy requires transportation agencies to use different construction materials from what they traditionally use. This may necessitate a change in agency culture or the adoption of new policies to ensure the use of alternative construction materials. However, with the abundance of transportation agencies in the U.S. having already used or using alternative construction materials, the political acceptance of this strategy is already high. Using alternative construction materials also provides other benefits such as less landfill for fly ash and slag, less smoke and odors from warm-mix asphalt, etc. Thus, it is likely to be publicly acceptable.
Road Surface	Road roughness results naturally from the gradual deterioration of road surfaces and/or the pavement structure. Not only do rougher roads reduce ride quality, they also reduce driver safety, increase vehicle wear and tear, and increase fuel consumption, which in turn increases greenhouse gas (GHG) emissions. Road resurfacing has been suggested as a way to improve fuel consumption and reduce GHG emissions. Yet, it is unclear whether resurfacing roads actually reduces GHG emissions due to the energy-intensive process of resurfacing roads.	Several studies have found that rougher roads increase vehicle fuel consumption, and thus carbon dioxide (CO_2) emissions, between 1% and 10%, depending on the type of vehicle (cars vs. trucks) and the roughness of the roads considered. A recent study showed that using stiffer pavements on the U.S. roads could reduce vehicle fuel consumption by as much as 3%. This would result in an annual decrease in CO_2 emissions of 46.5 million metric tons.	1. High	Not found in literature reviewed	3. Low: The overall effect of road surface improvements on fuel consumption and CO_2 emissions depends on many other factors. There are CO_2 emissions generated during road resurfacing such as from construction equipment and from travel delay due to road closure. After the resurfacing, there could potentially be induced travel demand (due to better driving conditions) and increased travel speed, which could increase vehicle fuel consumption and CO_2 emissions. Studies on the benefits of resurfacing rarely account for these effects. Additionally, the effects of road roughness on vehicle fuel consumption vary by the type of vehicles and the speed at which	1. High: Road resurface improvement projects are well perceived by the public as they increase driver comfort and satisfaction. Given the high costs and uncertainty about GHG benefits, road resurfacing is unlikely to be regarded as a major strategy for reducing GHG among transportation agencies. Instead, it would be more politically acceptable to consider any GHG reduction from road surface improvement projects as secondary benefits to the primary safety and mobility benefits.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Goods Movement (See Appendix D for references and further information)						
Double Stack Network for Rail	Double-stacked shipping containers allow trains to move twice as much load without needing to increase vehicle length, increasing the efficiency of freight movement.	One study found that among various forms of rail and truck transport, double-stack rail has the lowest CO_2 emission rate per ton-mile at 15.4 grams. Intermodal rail emits 17 grams per ton-mile, mixed freight rail emits 18.6 grams per ton-mile, and heavy truck emits the most CO_2 at 135.3 grams per ton-mile. Downsizing double-stack cars can further promote GHG reductions and fuel savings by allowing more cars to be linked per train, resulting in greater amounts of freight movement for less fuel. According to Amsted Rail, in a year, a length reduction from 48' to 40' leads to a CO2 reduction of 0.168 million tons annually, lowering emissions from 2,036,585 tons to 1,868,954 tons. Using the information provided by a Federal Railroad Administration's 2009 report, the National Gateway project to boost double-stack train usage between the Mid-Atlantic and Midwest US can achieve a 2 billion gallon fuel reduction and a 20 million ton CO2 reduction by converting 14 billion highway miles to double-stacked rail cars.	**1. High:** Rail networks generally serve interregional travel.	Not found in literature reviewed	1. High	2. Moderate: implementation of double-stack rail strategies involves a variety of public and private interests that work together to provide the funding and resources to improve double-stack rail infrastructure. As demonstrated by the National Gateway project in particular, resources and support can be provided by federal government, state governments, local authorities, politicians, environmental organizations, and companies that facilitate efficient freight transportation including ports, roads, and rail. Such partnerships reveal that double-stack rail networks have been supported economically, politically, and environmentally. Depending on the region, double-stack rail strategies may result in financial concerns since bridges, tunnels, and other rail infrastructure must be modified to accommodate this method of freight transport.
Intermodal Facilities Close to Ports	Due to their proximity to ports, intermodal container transfer facilities (ICTF) are locations that allow containers to be transferred between different modes, including ship, truck, and rail.	The Alabama State Port Authority notes that because ICTFs facilitate a more direct link between ship and rail, truck use can be reduced significantly. The Authority refers to the Environmental Protection Agency, which estimates that every ton-mile of freight moved by rail instead of road reduces GHG emissions by two-thirds, and that a single freight train can carry the load of approximately 280 trucks. It concludes from these numbers that an ICTF project could, over a 25 year span, reduce more than 240,000 metric tons of GHG emissions.	**1. High:** According to the Union Pacific Railroad, ICTFs play a key role in the interstate freight movement system by facilitating the distribution of cargo on both the regional and national level.	Not found in literature reviewed	**3. Moderate:** According to Union Pacific Railroad (2007), different analytical tools are used depending on the component of the ICTF that is being assessed. Calculated emissions from drayage trucks are based on the number of truck trips, the length of each trip, and the amount of time spent idling. Calculated emissions from cargo handling equipment and non-cargo related heavy equipment are based on the number and type of equipment, equipment model year, equipment size, fuel type, and annual hours of operation. Calculated emissions from reefer cars are based on the average size of units, the average number of units in the shipping yard, and the hours of operation for each unit.	**1. High:** According to one author, the public plays a key role in the development and siting of new ICTF projects. Public feedback and communication will play a pivotal part in public acceptance and/or resistance to the strategy.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Goods Movement (See Appendix D for references and further information)						
Ports and Marine Operations	Ships are the most energy-efficient means of moving goods, and as global trade and production continue to expand, emissions from port and marine operations are expected to grow. There are many measures to reduce GHG emissions of ports and marine operations, including ship speed reduction, ship size increase, hull and propeller optimization, improving ship engine efficiency, switching to other fuel alternatives, using electricity to power docked ships in port operations, autopilot upgrades, flow optimization, weather routing, hull cleaning, propelling polishing, waste heat recovery, air lubrication, speed-controlled pumps and fan, high-efficiency lighting, and solar power. The Port of Seattle has been able to reduce CO2 emissions by 26% annually by supplying ships with electric power rather than relying on the ships' diesel engines to supply power.	One study found that a 20-40% reduction in ship emissions can be achieved depending on the measures used. Another study found that operation efficiencies in marine transportation can reduce emissions by up to 47% in the short term, and an additional 27% by 2050. Speed reductions of 10 to 50% can result in immediate GHG emission reductions of 20 to 70% for container ships if no extra ships are needed to maintain the volume shipped. Hull and propeller optimization can reduce CO2 emissions by 28% for each new ship. By 2050, a combination of liquefied natural gas and wind power could reduce emissions by up to 40%.	**1. High:** Maritime activity is mainly interregional in nature.	Not found in literature reviewed	**3. Low:** There is a lack of available instruments to determine actual levels of emissions from maritime activity, resulting in a lack of data availability.	**3. Low:** Port and marine operations are transnational, resulting in complex social, economic, and political implications depending on the country or region. Locally controlled ports, for example, may wish to reduce emissions in the immediate port area but are constrained by limited jurisdiction and competitive pressures. National policy is constrained, as the government does not want to place American maritime fleets at a competitive disadvantage with fleets from other countries. Finally, not all nations with maritime activity are engaged with GHG reduction targets set by frameworks such as the Kyoto Protocol. The most politically acceptable strategies are ones that improve cargo handling efficiency, reduce operating costs at ports, and generate new traffic.
Mode Shift—Rail and Truck	Among the most common methods of freight transportation – truck and rail – the former accounts for most of the energy consumption. Strategies to increase rail usage can significantly reduce fuel consumption and GHG emissions.	One study revealed that rail was four times more fuel efficient than trucks, reducing GHG emissions by 75% if freight was shifted to rail. Furthermore, it was found that a 10% shift from truck to rail would result in a reduction of 12 million tons of GHG emissions. Another study revealed that up to 20 million tonnes of CO2 could be reduced in 2020 by making the rail network the primary means of freight transport.	1. High: Rail transport is often interregional.	Not found in literature reviewed	3. Moderate: There are several different analytical tools that can be used to analyze the effects of a model shift. They include the Marco Polo calculator, the EcoTransIT tool, the ICF tool and the NTMCalc tool. Ultimately, the recommended tool used to analyze the effects of modal shift on CO2 and fuel consumption depends on the available inputs and the preferred outputs, as well as the scenario.	3. Low: In comparison to the strategies in Europe and Japan, the U.S. lacks a large-scale funding program that directly incentivizes companies to pursue modal shift projects from truck to rail through grants or subsidies. Individual companies make the decision to pursue modal shift based on the market, as well as legislation that results in certain modes of transport (such as truck) becoming more cost-effective than others. Environmental impacts are only one of many factors that industries must consider in mode choice. They also look economic factors such as the production costs and price of transportation, as well as the quality of the transportation. Industries must also consider customer demand and how customers will respond to a modal shift or modal split. In addition, rail and road often deal with different shipment and trip types, making the modal shift from road to rail a more challenging effort than some studies indicate.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Goods Movement (See Appendix D for references and further information)						
Overweight Load Permits	Federal law limits the current maximum gross weight that a truck can carry on an interstate highway to 80,000 pounds. However, under special circumstances, some trucks must exceed these restrictions and are thus granted special permits by the state in order to legally carry out operations. The number of these permits, which apply primarily to federal and state roads, can impact the amount of annual GHG emissions from overweight trucks.	One report revealed that oversized and overweight vehicles contribute 43,000-75,000 tons of CO_2 a year, with 124.4 grams of CO_2 produced for each ton-mile that an extralegal truck travels. However, there have been no recent studies that provide concrete data as to how the distribution of overweight load permits directly affects GHG emissions.	1. High: This strategy applies mostly to interregional truck trips.	Not found in literature reviewed	**3: Low:** The primary uncertainties with data regarding overweight load permits come from regional variations in how permits are distributed, what kinds of permits are distributed, and how much extralegal weight is deemed acceptable. Any study of overweight load permits is typically limited to the state or region in which the research is conducted. There have been no recent studies that provide concrete data as to how the distribution of overweight load permits directly affects GHG emissions.	**3. Low:** The issue of oversized and overweight load permits tends to be primarily an economic and infrastructure concern. Discussions of how GHG reductions and fuel savings are affected by overweight load permits appear significantly less accessible, suggesting that overweight load permits have not been a priority in past or current climate change strategies. Railroad associations, such as the Ohio Railroad Association, oppose new permit strategies since these strategies often provide unfair subsidies for heavy trucks while simultaneously diverting freight traffic from rail to highways. Critics of overweight load permits believe that laws pertaining to these permits tend to only benefit powerful industries in the region they operate, such as logging in the West or oil and gas in Texas.
Truck Size and Weight Limits	GHG reductions and fuel savings can potentially occur from decreases in truck weights and increases in load weights. Federal law limits the current maximum gross weight that a truck can carry on an interstate highway to 80,000 pounds. Truck size and weight standards are regulated by the federal government with state enforcement of the regulations. Studies show mixed results and suggest that it is unclear how GHG emissions are impacted by policies that influence truck size and weight standards.	Reducing truck weight by 3000 pounds using lightweight materials such as cast aluminum alloy ultimately saves 240 gallons of gas and 2.44 metric tons of CO2. In 2001, the United Kingdom increased maximum truck weight from 38 tons to 44 tons, resulting in both fuel and CO2 savings. In 2001, 20.1 million litres/km of fuel and 53,800 tons of CO2 were saved. In 2002 39.1 million litres/lm of fuel and 104,800 tons of CO2 were saved, and in 2003 50.6 million litres/km of fuel and 135,700 tons of CO2 were saved. For vehicle loads, another study found that larger trucks carrying over 40 tons, despite higher fuel usage, demonstrated greater average CO2 efficiency than trucks below 40 tons, with a difference of 7 tkm/kg CO2. Smaller truck weights may imply greater emissions because smaller trucks will need to make more trips than larger trucks to transport the same load size.	1. High: Trucking is highly interregional in nature.	Not found in literature reviewed	3: Low: One way to measure the impact of truck weights on CO2 and fuel consumption is survey-based, where fuel efficiency estimates are determined by administering self-reported surveys based on different sizes and weights of trucks. The difference in values across surveys makes this survey-based data a tricky analytical tool for determining the impacts of truck weights. Another tool is vehicle test-cycle estimates, which utilizes a limited sample of vehicles that are tested and extrapolated to estimate weights and sizes of other vehicles. The primary concern with this type of analysis is that variable speeds across different traffic conditions cannot be accurately simulated through vehicle test-cycle estimates, resulting in an analysis that only reflects the conditions of the sample chosen.	3. Low: Policies to change truck loads and weights are often difficult to implement in the U.S. due to variations in regulation across different scales ranging from the federal to the local level. In the U.S., there are both strong proponents and critics of increased vehicle weights, which have consequently led to a lack of bipartisan support in Congress. There is also mixed opinion among truck drivers themselves. Approximately half strongly disagree or disagree that air quality, global warming, and fuel consumption are problems with the trucks they drive. Public concern for the increase in truck weight size comes primarily from reduced haulage costs that will consequently result in greater road freight movement generation and more freight traffic being diverted from rail to road. These public sentiments primarily reflect issues of safety and traffic caused by truck weights.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Goods Movement (See Appendix D for references and further information)						
Truck Stop Electrification	Truck-stop electrification (TSE) and auxiliary power unit (APU) technologies provide long-haul truckers with the ability to heat, cool, and power additional auxiliary devices at truck stops without requiring them to idle their engines. By providing these services, it is possible to reduce or altogether eliminate excess truck engine idling, thereby reducing GHG emissions.While the relative potential for TSEs and APUs to offset GHG emissions is significant, the absolute effect on GHG emissions from an individual APU or TSE is dependent upon the precise number of hours of idling that are offset.	Provided that trucks typically consume 0.8 gallons of diesel fuel per hour of idling, and that one gallon of diesel fuel emits 22.4 lbs of carbon dioxide (CO_2), an idling truck would produce 18 lbs of CO_2 per hour, or 90 – 180 lbs of CO_2 per day. In contrast, if a truck were to use an off-board TSE that draws 7.5 kilowatts per hour, given an average emission of 1.33 lb of CO_2 per kilowatt hour (kwh) from the electricity grid, then the truck would produce approximately 10 lbs of CO_2 per hour (a sizeable reduction compared to the 18 lbs of CO_2 per hour produced while idling). Another study, which reported that one hour of diesel engine idling produces 21.8 lbs of CO2 (equivalent to 131-174 lbs of CO_2 per day), found that utilizing an off-board TSE for the same purpose would draw only 4.3 kilowatts and emit 6.3 lbs of CO2 per hour (38-51 lbs of CO2 per day). In comparison, the report found that APUs emit only 4.1 lbs of CO2 per hour (25-33 lbs of CO2/day).	1. High: Trucking is highly interregional in nature.	Not found in literature reviewed	2. Moderate: One uncertainty regarding GHG reduction potential is the actual usage rate of TSE sites. While many TSE units can be constructed, their full utilization is not necessarily guaranteed, and their use can fluctuate over time. As a result, truck stops with TSE technologies could see varying levels of true GHG emission reductions. Variations in fleet efficiency, local climate, carbon intensity of electricity generation, and upkeep costs of TSE can further contribute to uncertainty. In addition, because TSEs and APUs provide truckers a less expensive alternative to power their truck cabins relative to engine idling, truck drivers may utilize their appliances and other services more frequently, potentially offsetting some of the GHG reductions.	1. High: There are no significant inter-agency or institutional concerns associated with APU use at this time. TSE facilities are generally accepted by the public for multiple reasons. TSE facilities provide truck stop operators and technology suppliers with additional business opportunities. These facilities can attract a greater number of truck operators who wish to save money on diesel fuel, and encourage them to stay longer and purchase other items and services from the truck stop operators. Similarly, APUs are also generally accepted because they tend to save truckers and fleet operators money. In addition, TSEs and APUs can reduce the noise and emissions that typically result from engine idling, thereby promoting an improved local air quality and environment.
Weigh in Motion	Weigh-in-motion (WIM) systems play a pivotal role in truck weight enforcement and infrastructure safety while simultaneously increasing the efficiency of freight traffic on roads. Sensors that track the axle loads of heavy vehicles are installed beneath asphalt surfaces on the mainline or on ramps, allowing for data to be captured and analyzed without the need for these vehicles to be stopped. WIM measures and stores information about axle weight, gross vehicle weight (GVW), axle spacing, vehicle length, vehicle width, and speed. WIM systems decrease idling at weighing stations, which has been found to have a connection with fuel consumption and GHG emissions.	WIM technology addresses the issue of long term idling, which represents any form of idling longer than 15 minutes. A 2004 U.S. survey reveals that idling heavy vehicles consume 3.2 litres of fuel per hour and have a CO2 emission factor of 2.6631 g/L. In New Brunswick, the baseline scenario for fuel consumption emissions in Waewig calculated a total of 57 litres of fuel consumed and 0.1373 kg/litres of CO2 emitted. A similar scenario in Salisbury East revealed a total of 19,052 litres of fuel consumed and 42.8732 kg/litres of CO2 emitted. Once the WIM stations were installed at these locations, it was found that only 1 litre of fuel was consumed and 0.0093 kg/litres of CO2 were emitted, a reduction of approximately 93%. Since 2011, over 1.4 million vehicles were cleared to pass Oregon weigh stations due to Oregon's Green Light Program, resulting in a 30,576,019 pound reduction of CO2 over the past 13 years.	1. High: This strategy applies mostly to interregional truck trips.	Not found in literature reviewed	3. Low: Size and weight enforcement is often difficult to implement due to the high level of data accuracy needed for optimal performance of WIM applications. The difficulty of calibrating sensors to accurately determine vehicle weights can lead to uncertainties in studies that evaluate how WIM sensors reduce unnecessary idling at weigh stations and affect GHG emissions and fuel consumption. Depending on the calibration of WIM sensors, data collection may be influenced by overweight trucks bypassing weigh stations or compliant trucks being forced to pull over at weigh stations.	2. Moderate: A survey was administered to truck operators by Nova Scotia Transportation and Infrastructure Renewal in 2008 to assess public opinion on fuel efficiency as a result of WIM systems. Nearly 6 in 10 respondents strongly agreed (9.1%) or agreed (50.6%) that their fuel efficiency was increased due to the new WIM system while over a quarter of respondents disagreed (24.2%) or strongly disagreed (2.2%) that fuel efficiency was increased.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Goods Movement (See Appendix D for references and further information)						
Low Emission Freight Corridors	Low emission zones (LEZs) and zero-emission corridors have been proposed as strategies to lower emissions from freight vehicles in urban areas without affecting the overall logistical efficiency of goods movement. LEZs provide urban access for vehicles that meet minimum emission standards and charge large daily fees for noncompliant vehicles 24 hours a day, 365 days a year. LEZs typically apply to heavy diesel vehicles since they contribute a large amount of air pollution when compared to other vehicles, but LEZs can potentially apply to all vehicles.	There are limited studies regarding the GHG reduction potential of low emission zones in Europe and zero-emission corridors in Southern California, as these strategies are focused primarily on improving air quality and reducing criteria pollutants from trucks.	3. Moderate: LEZs and zero-emission corridors may be for urban areas only and thus have little interregional impact. Or, they can be used to connect cities, in which case there will be an interregional impact.	Not found in literature reviewed	4. Very Low: LEZs and zero-emission corridors face a lack of quantitative data on GHG reductions, although findings on air pollutant emissions such as CO, HC, and NOx have been analyzed.	3. Low: While low emission freight corridors have not yet been implemented on a nationwide level, Southern California's proposal for zero-emission technology and a zero-emission freight corridor has been advocated on a federal level due to its relationship to the Moving Ahead for Progress in the 21st Century (MAP-21) bill. MAP-21 contains provisions for a national freight program that seeks out infrastructural and operational improvements that will reduce the impacts of freight by utilizing advanced technology. According to the South Coast AQMD (2011), political support and potential funding may come from agencies such as the U.S. Environmental Protection Agency, the Department of Energy, the California Air Resources Board, and the California Energy Commission. Discussions between these government agencies and manufacturers, suppliers, and testing facilities have already taken place, demonstrating growing political awareness toward zero-emission technology and zero-emission freight corridors.
Urban Consolidation Centers	An urban consolidation center is a logistics facility situated in close proximity to the area that it serves, allowing for consolidated deliveries to be carried out within that area and avoid congestion. After receiving shipments from numerous logistics companies, the UCC sorts and consolidates these loads into environmentally-friendly vehicles for delivery. Through this consolidation process, UCCs reduce the number of vehicle trips and miles, enable quicker turnarounds and loading/unloading, improve the efficiency of vehicle volume and weights, and make alternative modes and vehicles more feasible.	A study of Heathrow Airport's consolidation center found increasing CO2 savings per year, with 1,200 kg saved in 2003 and 3,100 kg saved in 2004. A UCC in Bristol saved 20.3 tons of CO2 and resulted in 6,945 fewer vehicle trips with 178,000 fewer vehicle kilometers traveled. A London UCC achieved approximately a 75% reduction in CO2 for deliveries from the consolidation center while reducing the number of construction vehicles traveling to delivery sites by 68%. A Monaco UCC reduced fuel and CO2 by 26% while reducing traffic congestion by 38%. Finally, a Stockholm UCC reduced energy use and CO2 by 90% while reducing vehicle kilometers per day from 64 km to 26 km (40 miles to 16 miles). North America, Japan, Australia and most of Europe have not expanded the UCC concept any further than studies and brief experiences with it, resulting in a lack of literature in the U.S. regarding this particular topic.	3. Low: This strategy mostly impacts emissions in the urban core.	Not found in literature reviewed	3. Low: Many of the uncertainties with UCC evaluation come from a lack of explanation regarding research methodology. For example, it is unknown whether UCC measurements in recent studies come from actual vehicle operations or from modeling work. In addition, most studies tend to evaluate UCCs and the transportation and environmental impacts in isolation from the total amount of transportation activity in an urban area, which prevents further analysis of how UCCs affect CO2 and fuel consumption in a larger context, such as on a regional or state-level.	3. Low: Due to the lack of support in the U.S., there has yet to be a uniform policy approach for promoting UCC strategies. However, cities such as Portland have reviewed UCC funding initiatives by the European Commission in order to assess the feasibility of implementing a similar sustainable freight practice within the U.S. If UCC strategies in Europe are an indication of how to approach policymaking in the U.S., then implementation of UCCs will require funding and support from both federal and local governments, as well as local authorities, freight and logistics companies, and key players within the supply chain. There is a general lack of awareness of how UCCs can provide numerous economic and environmental opportunities if established correctly.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Public Education/Behavior (See Appendix E for references and further information)						
Ecodriving: freight trucks	Eco-driving for freight trucks encourages a number of driving behaviors and vehicle maintenance practices that maximize fuel economy of existing vehicles while minimizing their carbon dioxide (CO2) emissions. Eco-driving principles include maintaining a constant speed, using a moderate speed on highway, accelerating smoothly, decelerating gradually using the engine brake, avoiding unnecessary idling, and keeping tires properly inflated. One method for incentivizing eco-driving habits is reward schemes centered on bonuses for every mile per gallon (mpg) of increased fuel economy. Another method for motivating drivers to continue using eco-driving principles is the usage of on-board monitoring systems.	A 2003 DHL Finland study found that the drivers of Air Express service recorded fuel savings of 17% per stop and 11% per kilometer after having received eco-driving training. A Canadian trucking company initiated a project in 2004 to provide eco-driving training to truck drivers and install monitoring technology in the vehicles to identify poor driving practices. The combination of these two practices resulted in reduced idling time from 48.3% to 17%, fuel savings of 3%, and an approximate annual reduction of 1,000 metric tons of CO2 emissions.	1. High: Trucking is highly interregional in nature.	Not found in literature reviewed	2. Moderate: Several factors can affect vehicle fuel consumption, including roadway type (e.g., city versus highway), vehicle weight, road grade, weather conditions, and congestion level. In eco-driving studies under real-world driving conditions, it may not be possible to control for all these factors during the driving periods with and without eco-driving (e.g., before and after receiving eco-driving training). Thus, the results may contain some biases due to differences in one or more of these factors, especially if the sample size is small.	2. Moderate: Based on interviews with regulators, educators, advocates, and managers in the freight industry in the U.S., they viewed eco-driving practices as the most effective way to reduce fuel consumption, but believed that it was most difficult to change driver behavior. Drivers can be resistant to change as they are used to driving in their preferred way. However, proper recognition and financial incentive can be a very effective way to encourage eco-driving habits. For fleet managers, high turnover rates in the industry lead many of them to be reluctant to invest in eco-driving training for fear of losing trained employees. For drivers, tight delivery schedules planned by dispatchers sometime cause them to prioritize speed over fuel savings.
Eco-driving: cars	Eco-driving is a collection of driving behaviors that increase vehicle fuel efficiency and thus reduce greenhouse gas (GHG), especially carbon dioxide (CO_2) emissions. Eco-driving principles include, for example, accelerating and braking gently, driving at moderate speed, avoiding unnecessary idling, using cruise control where possible, and anticipating traffic to avoid coming to a full stop. In a broader sense, eco-driving also involves properly maintaining and equipping the vehicle to achieve greater vehicle fuel efficiency and lower GHG emissions. This includes keeping appropriate level of tire pressure, removing unnecessary weight from the vehicle, using lower rolling resistance tires and lower viscosity motor oil, etc. Eco-driving principles can be introduced to drivers in one or a combination of the following ways: 1) raising public awareness about eco-driving through education and outreach campaigns, 2) providing eco-driving classes and/or training programs, and 3) equipping vehicles with on-board devices that provide real-time eco-driving	The evaluation results of various eco-driving training programs in Europe revealed that within one year of training, drivers reduced fuel consumption by 15 to 25%. After one year, fuel savings became less significant, ranging from 4.7 to 8%. In contrast to eco-driving training, there are very limited data on the effects of eco-driving education campaigns as they are more difficult to measure. For the aggressive national eco-driving campaign in Netherlands, with a total population of approximately 16.4 million people, 10 million licensed drivers, and 87 million vehicle miles traveled annually, it was estimated that the campaign saved approximately 0.2 million metric tons of CO_2 emissions from passenger cars annually.	1. Moderate: Passenger car driving can be both local and interregional.	Not found in literature reviewed	2. Moderate: Several factors can affect vehicle fuel consumption, including roadway type (e.g., city versus highway), vehicle weight, road grade, weather conditions, and congestion level. In eco-driving studies under real-world driving conditions, it may not be possible to control for all these factors during the driving periods with and without eco-driving (e.g., before and after receiving eco-driving training). Thus, the results may contain some biases due to differences in one or more of these factors, especially if the sample size is small.	1. High: There are no specific political concerns associated with eco-driving education and training programs. The social acceptability of such programs is likely to be high given that they are voluntary. Expenditures by individuals, government, and industry for eco-driving education and training will likely be negligible at a national level. As eco-driving technology is largely undeveloped, the costs to individuals, government, and industry for such technology is unknown but conceivably would be implemented as part of ongoing vehicle technology advancements.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Public Education/Behavior (See Appendix E for references and further information)						
Reduce Speed Limits	Speed limits and speed enforcement can play a role in reducing fuel consumption, which impacts GHG emissions. Another related strategy is indirect speed limit reduction through road redesign.	One study revealed that a speed limit reduction from 65 MPH to 55 MPH would reduce CO2 annually by 11,000 metric tons. On open roads with greater speed limits, another study found that lowering the speed from 130 km/h to 100 km/h (81 MPH to 62 MPH) in Austria resulted in a 25% reduction of CO2 while a related study in Netherlands resulted in a 34% reduction of CO2 when speeds were lowered from 111 km/h to 104 km/h (69 MPH to 65 MPH). However, emissions increase rapidly from 40% to 400% when speeds are lowered down from 25 km/h (16 MPH), resulting in a subsequent increase in energy consumption by a maximum of 57.5%. Another study argues that an 85 km/h (53 MPH) speed limit optimizes both travel times and emissions. A study by the Washington State Energy Office revealed annual savings of 933,000 metric tons of CO2 if 55 and 65 MPH speed limits were enforced.	2. Moderate: Speed limits are highly variable on a local level but speed limit policies are controlled at the state level.	Not found in literature reviewed	2. Moderate: Microscopic, mesoscopic, and macroscopic modeling can be used to relate emissions to driver speeds. The primary uncertainties with speed and GHG emissions data result from a lack of enforcement of speed limits and the inability to obtain direct measurements of the relationship between driving behavior and vehicle emissions, despite behavior and emissions sharing a strong correlation.	3. Low: Contemporary attitudes toward speed limit reductions are less supportive, and there have been pushes to increase the national speed limit to 70 MPH or higher, with individual states going as far as raising the speed limit to 70 MPH on their own. In Maryland, for example, the push for the 70 MPH speed limit has been motivated by great public support and the belief that higher travel costs, such as from tolls, warrant increased speeds. Ultimately, these current measures are receiving bipartisan support despite concerns of greater fatalities and subsequent raised insurance costs.

4.2 VMT Reduction Summary

The VMT reduction matrix (Appendix F) includes 26 strategies covering land-use planning, transportation alternatives, pricing, and public awareness. Historically, there has been a much stronger emphasis on policy to reduce VMT to manage congestion and air quality. As a result there is significantly greater understanding regarding strategies to reduce VMT than for system efficiency. VMT reduction strategies and research have focused to a greater extent on regional and urban impacts, rather than interregional. Literature and research compendium documents regarding VMT reduction strategies already exist that summarize GHG emissions reductions from VMT strategies. The VMT reduction matrix in Appendix F is based on the following sources:

- FHWA. Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources. February 2012. Prepared for FHWA by RAND Corporation and RSG, Inc.
- California Air Resources Board. Senate Bill 375 Research on Impacts of Transportation and Land Use-Related Policies. http://arb.ca.gov/cc/sb375/policies/policies.htm
- Ewing, Reid and Cervero, Robert. Travel and the Build Environment. Journal of the American Planning Association. May 11, 2010. http://dx.doi.org/10.1080/01944361003766766

Reference to the appropriate document is included in the strategy column of Appendix F. Elasticities were rarely referenced in these documents, although elasticity information may be available from other sources. The interregional impact of the strategies were estimated by the research team as follows:

Transportation Land Use Planning: Among the transportation and land use planning topics reviewed, none were estimated to have an overall high impact on interregional GHG emissions. This is not surprising, as land-use strategies tend to focus on urban, rather than interregional travel. However, a number of strategies were estimated to have moderate interregional impact, depending on the specific circumstances.

- Residential Density
- Transit Access and Transit Oriented Development
- Demand Management
- Smart Growth

The following transportation land use strategies were estimated to have a low or very low impact on interregional GHG emissions:

- Regional Accessibility
- Jobs-House Balance
- Infill
- Pedestrian Oriented
- Safe Routes to School
- Network Connectivity

<u>Transportation Alternatives:</u> Transportation Alternatives included two strategies that were estimated to have a high potential impact on interregional GHG emissions based on the literature:

- Intercity Passenger Bus and Rail
- High Speed Rail

Strategies that were estimated to have a moderate potential impact on interregional GHG emissions included:

- Ridesharing
- Employer-Based Trip Reduction
- Telecommuting

Transportation alternative strategies that were estimated to have a low or very low potential for reducing interregional GHG emissions included:

- Local Transit Expansion; Service Improvements
- Non-Motorized transportation
- Fare Measures
- Carsharing

Pricing System Use: Three of the pricing strategies reviewed were estimated to have a high potential impact on GHG emissions from interregional travel:

- VMT Fees
- Intercity Tolls
- Pay-As-You-Drive Insurance

Pricing strategies that were estimated to have a moderate impact on GHG emissions from interregional travel included:

- Congestion Pricing
- Parking Management

Commuter incentives was estimated to have a very low interregional impact.

Public Awareness: Voluntary travel behavior change was estimated to have a low interregional impact.

5. Conclusion and Recommendations

The research indicates there are both opportunities and challenges for reducing GHG emissions from interregional travel. The expert interviews and literature summaries provide Caltrans with information to assist with: 1) prioritizing which GHG emission reduction strategies for interregional travel California should focus on, 2) understanding the potential magnitude of emissions reduction from strategies where data is available, 3) developing level of confidence estimates for various strategies, and 4) gauging social/political acceptability of strategies. The expert interviews provide information about MPO and RTPA strategies and assessment of interregional GHG emissions that can further assist Caltrans with research and planning, as well as development of the California Transportation Plan.

The MPOs and RTPAs that participated in the interviews indicated the following regarding agency strategies that impact interregional GHG emissions:

- All agencies are including interregional GHG reduction strategies in their plans. The most common strategies are land-use/density approaches, rail, interregional transit, high-speed rail, and transportation demand management.
- Agencies are employing a mix of interregional strategies that were modeled and strategies evaluated off-model.
- Most respondents were unable to provide elasticities for strategies, but said Caltrans could contact their agency for further technical information about their modeling.
- Several agencies discussed their inability to accurately measure interregional GHG emissions due to the lack of an acceptable statewide model. [Caltrans has since stated that an acceptable statewide model will be made available to the MPOs Spring 2014.]
- Several agencies recommended that Caltrans take more leadership on completing the Statewide Travel Demand Model, so that agencies can make more accurate estimates of interregional travel-related GHG emission reductions.

The MPOs and RTPAs all indicated they were including interregional GHG reduction strategies in their plans, though in varying degrees. Several described interregional strategies as a minor component of their overall planning, while others listed a significant number of strategies. Several strategies are being employed by multiple agencies, including:

- land-use/density approaches: 6 agencies
- some form of rail (not including high-speed rail): 5 agencies
- interregional transit or bus: 5 agencies
- high-speed rail: 4 agencies
- carpools, vanpools, and other transportation demand management strategies: 3 agencies
- ridesharing: 2 agencies
- jobs-housing balance: 2 agencies
- traveler information/message signs: 2 agencies

Both the opportunities and challenges suggest the need for additional research for a greater understanding of interregional GHG emissions impacts and the most appropriate policy mechanisms to achieve the goals. Opportunities include:

1) Goods movement, especially mode shift from truck to rail when appropriate and development of strategies and policy from a perspective that views goods movement in total from origin to destination, including interregional travel and moving the goods into urban regions to point of delivery. What policies are best to reduce goods movement GHG emissions and what federal, state and local-level strategies would be most effective at reducing GHG emissions.
2) Work closely with MPOs and RTPAs to increase the GHG reduction benefit from alternative (non single occupancy vehicle) modes of interregional travel, including local linkages that are easy and accessible for the traveling public to maximize use of the interregional alternative mode as well as the local alternative mode.
3) Develop greater understanding of interregional travel characteristics in California and identify appropriate strategies, including relative contribution to GHG emissions. For example, interregional travel in areas affected by congestion will

benefit from congestion management, while interregional travel between urban centers may benefit from strategies to develop alternative modes and ridesharing.

4) Modifying construction practices and materials may provide significant GHG reduction benefits.
5) Improve communication between Caltrans and MPO technical modeling staff to share data, elasticities, and off-model strategies.
6) Investigate how Caltrans can work with the MPOs and RTPAs when developing interregional strategies, similar to how the MPOs and RTPAs work closely with local agencies in their regions to develop their plans.
7) An important theme for the MPOs and RTPAs was the importance of developing GHG strategies that have other non-GHG benefits for communities. Caltrans may want to explore how to identify and maximize co-benefits from interregional GHG emissions reduction strategies.
8) Promising strategies to reduce interregional GHG emissions from system efficiency include:
    - Construction Materials (high)
    - Road Surface (high)
    - Double Stack Network for Rail (high)
    - Intermodal Facilities Close to Ports (high)
    - Ports and Marine Operations (high)
    - Mode Shift to Rail from Truck (high)
    - Overweight Load Permits (high)
    - Truck Size and Weight Limits (high)
    - Truck Stop Electrification (high)
    - Weigh in Motion (high)
    - Ecodriving for trucks (high)
    - Low Emission Freight Corridors (moderate)
    - Incident Management (moderate)
    - Integrated Corridor Management (moderate)
    - Transportation Systems Management: ITS (moderate)
    - Ramp Metering (moderate)
9) Promising strategies to reduce interregional GHG emissions from reducing VMT include:
    - Intercity Passenger Bus and Rail (high)
    - High Speed Rail (high)
    - VMT Fees (high)
    - Intercity Tolls (high)

- Pay-As-You-Drive Insurance (high)
- Residential Density (moderate)
- Transit Access and Transit Oriented Development (moderate)
- Demand Management (moderate)
- Smart Growth (moderate)
- Ridesharing (moderate)
- Employer-Based Trip Reduction (moderate)
- Telecommuting (moderate)
- Congestion Pricing (moderate)
- Parking Management (moderate)

Additional challenges identified include:

1. The need to develop adequate tools to assign GHG emissions and responsibility for interregional trips.
2. Lack of interregional transportation data, especially in smaller regions.
3. Lack of off-model rule of thumb GHG reduction assumptions that are applicable interregional and to smaller regions.

There are substantial opportunities to reduce GHG emissions from interregional travel, although many strategies are currently challenging to quantify. Continued research to identify opportunities and develop quantifiable impacts will strengthen Caltrans strategic planning and strategy to reduce GHG emissions from interregional travel for the California Transportation Plan.

APPENDIX A

EXPERT INTERVIEW QUESTIONNAIRE

I. Introduction

Caltrans wants to learn from the work of regional planning organizations around CA to identify and develop strategies to reduce GHG from transportation. By collecting the experiences and lessons of the region, Caltrans hopes to identify policies and strategies that can reduce interregional greenhouse gas emissions and ultimately incorporate those strategies into the state transportation plan.

- **a.** Identify/confirm name, position, and organization (MPO/RTPA/Other) of interviewee.
- **b.** Is your region classified as:
  - Large Urban (200,000 and more)
  - Urban (50,000 to 199,999)
  - Non-Urban/Rural (49,999 or less)
  - Other
- **c.** Note date and time at which the interview took place.

II. Preliminary Information *(short answers are ok):*

- **a.** What is [agency name] role in reducing GHG emissions from transportation?
  - i. *(Ask only MPO)* What is [agency] reduction goal (percent) from (base year)? That you have been assigned by CARB? Baseline 2005?
  - ii. *(Ask only RTPA)* Is your agency voluntarily promoting GHG reduction strategies?
  - iii. Do you consider this to be a reasonable goal?
  - iv. What are some key barriers in achieving this goal?
- **b.** As an employee, what are your tasks/responsibilities regarding [agency] effort to reduce GHG emissions?
- **c.** What is the current status of [agency] planning document for GHG emissions reductions, such as regional transportation plan and/or sustainable community strategy? (Just started, 1/3 through, ½ through, 2/3 through, ¾ through, almost complete, approved?) Still scheduled for March 2014 adoption?
- **d.** If I am reading the presentation on your website about the draft scenarios in your SCS correctly, has CARB assigned targets of 10 percent per capita GHG reduction by 2035 – correct? What is the CARB target for 2020?
- **e.** Have you selected the preferred scenario? What are the GHG reductions that your scenario achieves in 2020 and 2035?
- **f.** According to the performance indicator chart I found on your website, it looks like all four scenarios in your SCS planning exceed the 2035 GHG target – correct? Do they also all exceed the 2020 target?
- **g.** How much of those reductions are coming from transportation?

III. GHG Reduction Planning Process *(short answers are ok):*

- **a.** How did (or is) [agency] considering and selecting GHG reduction strategies for your regional transportation plan or other planning document?
    - i. How did (or is) [agency] prioritizing what strategies to focus on?
- **b.** Local support:
    - i. Do you think the residents of the cities and counties in your region support your SCS/APS (Alternative Planning Strategy)?
    - ii. Do you think the elected officials of the cities and counties in your region support your SCS/APS?
    - iii. Please share some of the key suggestions that your region's cities and counties offered in this process.
- **c.** Emission calculations: [according to your schedule looks like these will happen in early 2014]
    - i. During your planning process how were baseline carbon dioxide emissions for your region determined?
    - ii. How did [agency] determine which transportation emissions to count in your analysis?
        1. Did you use CARB's Regional Targets Advisory Committee (RTAC) recommended trip-end attribution of GHGs, geographic attribution, or some other attribution method?
- **d.** Were there (or are there) technical uncertainties with modeling/ forecasting GHG emissions reduction from your agency's GHG reduction strategies?
    - i. If so, what are the primary uncertainties:
        1. Lack of modeling tools / lack of staff expertise / lack of data / lack of information on best practices / lack of elasticities?
    - ii. If so, can you tell us which GHG reduction strategies you could not use in your modeling?
    - iii. How did/if/will [agency] acknowledge emissions reductions from strategies that could not be modeled?
- **e.** Did (or will) [agency] factor in social and political acceptability of the selected strategies?
    - i. If yes, in what way were these considered when [agency] selected strategies?
    - ii. Were there any promising strategies that were not included in your regional transportation plan [or other planning document] because of anticipated social or political influence/resistance?
        1. If yes, can you please share them with us?
    - iii. Were there any strategies that were included in your plan primarily because of anticipated or real social or political influence?
        1. If yes, can you please share them with us?
- **f.** Did (or will) [agency] factor in cost when selecting strategies?
    - i. If so, how did cost impact your decision-making?

ii. If not, why not?

g. What additional information/research would significantly improve [agency] GHG reduction plan?

IV. Interregional travel related GHG Reduction Strategies *(HIGH IMPORTANCE, request detailed answers).*

a. Please share a few key strategies in [agency] plan that would reduce interregional GHG emissions?

i. Modeled Strategies (for interregional):

1. How did you estimate the magnitude of emission reduction from promising interregional strategies?
2. What is the level of confidence in your estimates?
3. Can you share elasticities for some key strategies?
4. How were the elasticities computed (data sources, empirical (data) of theoretical (model) results)?

ii. Post-processed/off-modeled Strategies (for interregional): [*see definition of post processed/off-modeled below]*

1. Did you include any interregional strategies even though they could not be included in your standard modeling process?
2. Can you tell me which strategies did not fit into your modeling?
3. How did you estimate the magnitude of emission reduction from these strategies?
4. What is the level of confidence in your estimates?
5. Can you share elasticities for some key interregional strategies that you post-processed?
6. What is your source for the post-processed elasticity? *[answer would be something like peer reviewed publication, internal modeling expert, etc.]*

b. Please share a few key interregional travel related GHG reduction strategies that [agency] will consider in the next plan update that are not included in the current plan and/or that we have not discussed thus far.

c. Are there interregional travel related GHG reduction strategies (regardless of whether included in [agency] plan) that you think Caltrans should lead?

i. If yes, probe for details about the strategies and why they think the strategies are better suited for a state department of transportation such as Caltrans.

V. Goods Movement related GHG Reduction Strategies *(HIGH IMPORTANCE, request detailed answers).*

a. Please share a few key strategies in [agency] plan that would reduce goods movement related GHG emissions?

i. Modeled Strategies (goods movement):

1. How did you estimate the magnitude of emission reduction from promising goods movement strategies?

2. What is the level of confidence in your estimates?
3. Can you share elasticities for some key strategies?
4. How were the elasticities computed (data sources, empirical (data) of theoretical (model) results)?

ii. Post-processed/off-modeled Strategies (goods movement): *[see definition of post processed/off-modeled below]*

1. Did you include any goods movement strategies even though they could not be included in your standard modeling process?
2. Can you tell me which strategies did not fit into your modeling?
3. How did you estimate the magnitude of emission reduction from these strategies?
4. What is the level of confidence in your estimates?
5. Can you share elasticities for some key goods movement strategies that you post-processed?
6. What is your source for the post-processed elasticity?

b. Please share a few key goods movement related GHG reduction strategies that [agency] will consider in the next plan update that are not included in the current plan and/or discussed thus far.

c. Are there goods movement related GHG reduction strategies (regardless of whether included in [agency] plan) that you think Caltrans should lead?

i. If yes, probe for details about the strategies and why they think the strategies are better suited for a state department of transportation such as Caltrans

VI. GHG Reduction Strategies and Caltrans (*MEDIUM IMPORTANCE, short answers are ok)*

a. Are there any promising GHG reduction strategies that [agency] has assessed that should be developed / promoted in partnership with Caltrans?

i. Which strategies and why?

b. Are there any other GHG reduction strategies (regardless of whether included in [agency] plan) not previously discussed in this conversation that you think Caltrans should lead?

i. Which strategies and why?

c. Can you think of any innovative strategies that other jurisdictions could implement that might reduce GHG emissions

i. Which strategies and why?

d. What are your recommendations to Caltrans as they develop the next update to the California Transportation Plan?

e. Do you have reports or technical people on your staff that you recommend to Caltrans for further information?

f. Is there anything we didn't talk about that you would like to share with Caltrans?

g. Are there any agencies or entities that [agency] would like to refer Caltrans to for more information regarding GHG strategies?

VII. GHG Reduction Strategies *(LOW IMPORTANCE, complete only if there is time)*

a. Broadly, what categories of GHG emissions reduction strategies did your agency pursue (e.g.: reducing VMT, transit, land-use, density, parking, other, etc.)

b. What strategies that are included (or being considered) in [agency] plan do you believe are the most effective at reducing GHG emissions?

- i. Why do you believe these will be the most effective?
  1. Strategy has high reduction potential
  2. Implementation is financially feasible
  3. Implementation is politically feasible
  4. Agency has full control over implementation
  5. Has a history of prior success

c. What strategies are included in [agency] plan that you consider to be least likely to reduce GHG emissions?

- i. Why do you believe these will be least effective?
  1. Strategy has a lower reduction potential
  2. Implementation is financially difficult
  3. Implementation is politically difficult
  4. Agency lacks control over implementation

d. Can you name/describe any strategies that [agency] pursued, but did not select in the final document?

- i. Why?

e. Can you describe any strategies that [agency] is including, but with a minor emphasis?

- i. Why the minor emphasis?

f. Measuring effectiveness:

- i. Have you been measuring the success of each of your past strategies? If yes, how?
- ii. How do you plan to measure the success of each of the proposed strategies?

g. Does [agency] have any current partnerships with other entities regarding development/promotion of promising strategies?

- i. If so, which one(s)?

Thank you for your time to participate in this interview. If we have follow-up questions based on your responses today may we contact you?

Interregional trip types as defined by the Regional Target Advisory Committee Report for SB 375 are as follow:

- Trips that begin in a Metropolitan Organization (MPO) or Regional Transportation Planning Agency (RTPA) region and end in another region (region to region)
- Trips that travel through a region but begin and end outside of the region (through trips)
- Trips that begin in a region but do not end in a region (international, interstate, tribal land, and military base)
- Trips that end in a region but do not begin in a region (international, interstate, tribal land, and military base)

Definition of elasticity:
An elasticity is a value that measures the change in transportation demand/consumption (such as VMT) due to changes in factors such as prices (like parking fees, road tolls and transit fares) and transit service quality.
A positive elasticity means that an increase in a factor leads to an increase in transportation consumption.
A negative elasticity means that an increase in a factor leads to a decrease in transportation consumption.
An elasticity greater than 1 or less than -1 means that a change in a factor leads to a more than proportional change in transportation consumption.

Post processed/off-modeled:
Post processing/off-model is when the data or elasticities cannot be used within the model because the model doesn't have the computing capacity to handle these data. The data pertaining to the strategy is used to account for quantitative GHG impacts outside of the model.

Goods movement, also known as freight, refers to the transport of commercial goods. Goods movement includes long haul between states, and regions, as well as within an MPO or metropolitan area. Goods movement includes rail, truck, and marine transport.

APPENDIX B

OPERATIONAL EFFICIENCY

LITERATURE REVIEW

Incident Management

I) Brief Summary of the Strategy including history if appropriate to provide context

A report by the Texas Transportation Institute in 2009 estimated that traffic incidents account for roughly 60% of traffic delay experienced in the 50 largest U.S. cities (FHWA 2012). According to a Caltrans report published in March 2010, it was estimated that traffic incidents account for about 25 percent of traffic congestion and delay (CTC & Associates 2010).

Incident management programs are utilized by many departments of transportation worldwide to identify, analyze, and correct minor and major traffic incidents to help mitigate traffic backups, as well as increase public safety. Recent developments in the field of Intelligent Transportation Systems (ITS) have allowed some incident management programs to utilize radar, lasers, and video surveillance to more effectively detect and respond to traffic, improving efforts to alleviate traffic congestion and reduce delay time and cost. Because incident management can reduce traffic delay and congestion, it may also reduce fuel consumption and resulting greenhouse gas (GHG) emissions.

While incident management programs vary from state to state, they generally include three primary functions: traffic surveillance (the process of detecting and verifying traffic incidents), clearance (coordinating emergency response teams to the site of the incident), and traveler information (notifying motorists of the incident through changeable message signs to provide time to select an alternative route) (Shaheen 2007).

Although the employment of incident management strategies primarily serves to reduce traffic congestion and improve roadway safety, the following literature review will focus on the potential fuel and GHG emission reductions of incident management programs.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

In 1998, incident related congestion and delay within the 10 most congested urban areas in the U.S. ranged from 218,000 to 1,295,00 person-hours. During this incident related congestion it was estimated that an additional 56.5 to 328.3 million gallons of gasoline were consumed (Farradyne, 2000). The consumption of this fuel would result in the emission of an additional 0.5 to 3.4 million tons of CO_2 (FHWA 2012).

Incident management programs, by reducing incident clearance times and delay, can greatly diminish fuel consumption and resulting GHG emissions. The FHWA (2012) found that studies of the GHG benefits conducted throughout the U.S. show varying impacts on GHG emissions reduction per incident, ranging from 2 metric tons of CO_2 to 23 metric tons of CO_2 compared to situations with no incident management.

Below summarizes several studies that pertain to incident management and GHG emissions:

A life cycle assessment that compared the benefits of incident management systems to those of green construction practices estimated through simulation that incident management programs could save 51,000 gallons of gasoline annually, and subsequently 416 metric tons of CO_2 (Tupper et. al 2012).

The Maryland CHART (Coordinated Highways Action Response Team) is a statewide program that incorporates an array of sub systems including traffic monitoring, traveler information, incident management, and traffic management. The system includes a variety of communications infrastructure used to monitor current traffic conditions, such as closed-circuit televisions (CCTV) and other advanced interfaces for traffic detection systems. In addition, variable message signs (VMSs), traveler advisory radio (TAR) transmitters, and highway advisory telephone systems have also been put in place to support motorist information needs (MD DOT 2013). In particular, CHART's incident management program was estimated to reduce total delay time from 32,814 traffic incidents by 29.98 million vehicle-hours, and reduce overall fuel consumption by 5.06 million gallons (Chang et. al 2003). This equates to approximately 154 gallons of fuel and 1.3 metric tons of CO_2 saved per incident. Because the state of Maryland is a member of the I-95 Corridor Coalition, a group comprised of 26 distinct agencies/organizations responsible for transportation along the northeast section of the I-95 corridor from Virginia to Maine, the CHART program also plays a significant role in interregional travel. The primary objective of the I-95 Corridor Coalition is to "work cooperatively to improve mobility, safety, environmental quality and efficiency of inter-regional travel in the northeast through real-time communication and operational management of the transportation system." (MD DOT 2013).

Florida's Road Ranger program, part of the SMART (Systems Management for Advanced Roadway Technologies) ITS deployments package, was estimated to save approximately 1.8 million gallons of gasoline and 14,000 metric tons of CO_2 emissions annually (Florida DOT 2005). The Road Ranger patrols are designed to assist incident responders in lane clearance and traffic control during major incidents, as well as provide additional services to motorists in distress by providing limited amounts of fuel, tire changing assistance, and other minor repairs; in total the road ranger program assisted in 351,941 incidents (Florida DOT 2005).

Other reports have shown much higher fuel savings per incident. The Federal Highway Administration reported that a study of the San Antonio Texas TransGuide System found savings of 2,600 gallons of fuel and 23 metric tons of CO_2 saved per major roadway incident (FHWA 2012). The Texas Transguide is a network of ITS technologies that currently operates on 100 miles of San Antonio area freeway. The system utilizes various technologies to detect incidents and warn motorists, including:

- "Dedicated divergently-routed fiber-optic rings and associated communications equipment
- Over 2,500 inductive loop, acoustic, radar, or video-recognition (VIVDS) traffic detectors at 220 total locations
- 185 closed-circuit, remote-controlled video cameras
- 220 main-lane and frontage road Dynamic Message Signs (DMS)
- 246 Lane Control Signal (LCS) systems *(currently switched-off due to maintenance funding limitations)*
- Three-story Traffic Operations Center (TOC)
- Distributed computer system, specialized software, and related equipment" (Texas DOT 2013).

The studies above indicate that emissions reductions, from the implementation of incident management programs, can range from 1.3 metric tons of CO_2 to 23 metric tons of CO_2 per incident.

b. <u>Qualitative discussion about GHG reductions or fuel saving</u>

In general, fuel and emissions reductions achieved by incident management programs seem to be promising. It is important to understand, however, that fuel savings and emissions reductions will vary year to year based on weather conditions, traffic volumes, as well as location of incident management implementation (Tupper et. al 2012).

c. *<u>Elasticities (if available)</u>*

N/A.

d. <u>Analytical tools for analysis (if available)</u>

Various modeling and simulation software, such as PARAMICS and EPA MOVES, were utilized to compute the fuel and emissions savings in the above studies.

e. <u>Uncertainties/qualifications to the data</u>

Estimates of traffic delay reductions depend on a number of prevailing traffic conditions such as: traffic volume, incident topology, and roadway characteristics in the region where services are provided. Because these conditions can vary significantly from region to region, it is difficult to generalize results across different programs. In addition, data from these programs do not explicitly account for induced demand, which may reduce or negate the fuel and emission reduction benefits of incident management programs (FHWA 2012).

Ultimately, the effectiveness of a particular incident management program depends on numerous factors, including the number and type of incidents that occur in the region, the level of congestion that results from that incident, and the speed with which the incidents can be cleared.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

As of 2009, there were approximately 272 incident management programs within the 439 U.S. urban areas (Schrank & Lomax 2009). In 2004, 32% of freeway miles in the U.S. were monitored by video surveillance to detect incidents, and 45% of those miles were covered by roadway patrols (USDOT 2007).

According to a 2012 report by the Federal Highway Administration, slightly more than half of major urban areas have some type of incident management program. Some specific examples cited in the report included the following:

- Maryland (MD DOT 2013);
- San Francisco Bay Area/Highway Service Patrol (Metropolitan Transportation Commission 2013);
- Florida (Florida DOT 2012);
- Arizona (Olmstead 2001);
- Houston, TX (City of Houston 2007);
- Portland, Oregon (Bertini et al. 2005);
- Seattle, WA (Nee and Hallenbeck 2001); and
- Minnesota/Highway Helper (Minnesota DOT 2002).

b. What policy mechanism was used?

Incident management systems coordinate efforts between intelligent transportation systems (ITS) and roadway service patrols. The patrols tour congested or high incident sections of freeway to identify traffic incidents and minimize their duration and disruption of highway traffic flow. By doing so, these patrols are capable of restoring roadway capacity and limiting the risk of secondary incidents (Farradyne 2000). ITS infrastructure, such as changeable message signs, computer-aided dispatch, and closed circuit television, are utilized in conjunction with roadway patrols to aid in the detection and identification of roadway incidents.

c. Results? Success? Uncertainties?

N/A

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Incident management systems are run either exclusively by the public sector, or through public-private partnerships. In general, these programs can be undertaken by local, state, or regional transportation agencies in conjunction with law enforcement and emergency response services. Metropolitan Planning Organizations (MPOs) may also support incident management programs if provided the proper funding and support system. DOTs and MPOs can work together with elected officials, police agencies, and city/county transportation agencies to undertake these programs and coordinate management (Farradyne 2000).

Because incident management programs may require coordination across multiple jurisdictions and may include a variety of actors and relationships within the levels of government (municipal-municipal; municipal-state, etc.), the process of implementation may become complicated (Johnson et. al 2001).

b. *What is the policy*

N/A

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

Incident management programs are generally acceptable given the time and fuel savings benefits that they offer to motorists. Although generally accepted, programs may require inter-agency coordination across jurisdictions and transportation facilities to implement the programs in full (FHWA 2012).

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

Evaluations of incident management programs have shown the public is generally in favor of their operation (Farradyne 2000). The Florida Department of Transportation reported that its incident management program, Road Rangers, receives positive comments from the public through comment cards distributed at each service call (Florida DOT 2012). Despite generally positive reviews, it has been observed that public relations campaigns are necessary to maintain high levels of support and understanding for the programs, and to protect the relationships between partnering agencies (USDOT 2001).

b. *Public issues concerns regarding the strategy*

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

The associated costs of implementing an incident management strategy depend on the specific technology and approaches used, and are likely to vary per incident. An agencies' cost for an incident management program includes operating and managing the service patrol (vehicles and staff), as well as implementing and maintaining the ITS technologies (U.S. DOT 2007).

Costs can vary greatly from region to region. The Federal Highway Administration reports that the Florida Road Ranger Program cost $2.5 million in 2005, or roughly $93 per incident; whereas the Los Angeles Metro Freeway Service Patrol program costs $21.3 million per year (RITA 2006).

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Integrated Corridor Management

I) Brief Summary of the Strategy including history if appropriate to provide context

According to an FHWA report, the greatest concentrations of traffic congestion occur along transportation corridors that link residential areas, business centers, shopping centers, and sporting arenas (Cronin et. al. 2010).

Integrated corridor management (ICM) is a strategy to maximize the effectiveness of intelligent transportation systems (ITS) to mitigate congestion along the most heavily trafficked transportation corridors. More specifically, ICM refers to the coordination of network and control systems along multiple transportation corridors to create a more interconnected system capable of effectively managing traffic and system demand using communication and sensory technologies. Through this integration, ICM seeks to optimize the use of available infrastructure by directing travelers to underutilized capacity within the transportation corridor. Specific strategies include motorists shifting their trip departure times, routes, or modal choices. Additionally, departments of transportation (DOTs) can dynamically adjust metering rates at entrance ramps, or adjust traffic signal timing to accommodate fluctuations in traffic demand. ICM seeks to provide travelers with real time information that enables them to shift their travel itineraries in response to changing traffic conditions. The goals of ICM are to decrease traffic congestion, improve travel time, reduce fuel consumption and resulting emissions, and also increase the overall reliability of traffic systems.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

There are several ICM corridors located throughout the United States that are currently in the preliminary testing phase. The United States Department of Transportation anticipates that independent evaluations of all of the ICM demonstration sites will be developed by the end of 2014, to determine whether or not ICM strategies deliver the expected benefits. Currently, ICM research involving analysis, modeling, and simulation on several test corridors (San Francisco, CA; Dallas, TX; Minneapolis, MN; and San Diego, CA) indicate that corridors that implement ICM can expect greater travel time reliability and productivity of corridor networks, and reduced fuel consumption and emissions (Cronin et. al. 2010)

Several studies estimate the potential annual benefits of ICM. The ICM Analysis, Modeling and Simulation (AMS) effort helped improve analysis tools and methods for the integration of ITS technologies within transportation corridors, and helped to develop expected benefits for several of the pioneer ICM testing sites (Alexiadis 2008; Alexiadis 2011; Miller & Skabardonis 2010) .

A Cambridge Systematics Inc. study estimated annual fuel and emissions savings for the San Diego, Dallas and Minneapolis ICM projects. The report predicted annual fuel savings of 323,000 gallons (San Diego), 981,000 gallons (Dallas), and 17,600 gallons (Minneapolis) (Alexiadis 2011). This would correlate to approximately 6 million, 17.6 million, and 316,800 lbs of annual CO_2 reductions for the three sites respectively. The report also estimated annual mobile emissions reductions of 3,100 tons (San Diego), 9,400 tons (Dallas), and 175 tons (Minneapolis) (Alexiadis 2011).

Alexiadis (2008) analyzed the potential impacts of certain ITS technologies along the ICM test corridor between Oakland and Fremont California under different traffic conditions. The test corridor between the two cities comprises 34 miles (250 lane miles) of the I-880 corridor, with the I-580/I-80 interchange as the northern boundary and SR 237 as the southern boundary. The results from these simulations are shown in the tables below:

Major Incident Scenarios - Annual Benefit (Million – Gallons of Fuel Saved)							
ITS Strategy	HOT Lane	Highway Travel Info	Transit Travel Info	Adapt RM	Signal Coordination	HOT + Travel Info	Combo
Medium Demand With Major Incident	3.9	1.4	0.4	-1.4	1.3	7.3	3.1
High Demand With Major Incident	6.0	1.9	0.6	0.7	2.4	7.3	4.6

Minor Incident Scenarios - Annual Benefit (Million – Gallons of Fuel Saved)						
ITS Strategy	HOT Lane	Highway Travel Info	Transit Travel Info	Adapt RM	Signal Coordination	HOT + Signal Coordination + RM
Medium Demand With Minor Incident	3.5	No Data	No Data	-1.0	1.2	3.6
High Demand with Minor Incident	6.6	No Data	No Data	0.5	2.0	6.3

b. *Qualitative discussion about GHG reductions or fuel savings*

There are an estimated 300 corridors in the country that have underutilized traffic capacity that could benefit from the implementation of ICM technologies (Alexiadis 2008). ICM technologies can affect fuel consumption and resulting emissions through changes in Vehicle Miles Traveled (VMT), person throughput, mitigation of delay, and speed of traffic alterations. The direct benefits of an ICM system (ICMS) are hard to measure because they are, in effect, a "system of systems" (Zhang et. al. 2010); meaning that the benefits achieved by ICM implementations are achieved through the coordination of ITS technologies, not the individual ITS technologies themselves. Results achieved by Analysis Modeling and Simulation (AMS) showcase that ICM strategies are most effective and produce the greatest level of benefits during higher levels of demand and during periods of non-recurrent congestion (Alexiadis 2008).

c. *Elasticities (if available)*

N/A

d. Analytical tools for analysis (if available)

Analysis, Modeling and Simulation (AMS) tools were used to study the potential benefits of ICM. This approach applied macroscopic, mesoscopic, and microscopic transportation analysis to analyze a variety of transportation factors including mobility, reliability, safety, emissions, fuel consumption and benefit-cost ratio. Macroscopic analysis was used to determine overall trip patterns, mesoscopic analysis was used to determine the impact of driver behavior in response to ICM strategies, and microscopic analysis was used to determine the impacts of traffic control strategies at roadway junctions. In addition to analyzing normal traffic scenarios, the analysis also took into account non-recurrent traffic conditions.

ICM strategies that were analyzed through AMS include highway traveler information, transit traveler information, freeway ramp metering, HOT lanes, arterial traffic signal coordination and varying combinations of these strategies. Performance measures were then reported by mode, facility type and jurisdiction (Alexiadis 2008).

e. Uncertainties/qualifications to the data

The data above are estimations of the potential benefits of ICM technologies. As such, real world results could achieve higher or lower levels of benefits. Additionally, the effects of ICM depend on the size of the corridor, the particular ITS technologies utilized, the coordination of such ITS technologies, and the initial level of traffic congestion and underutilized system capacity.

III) **Where has the strategy been implemented (if applicable)**

a. Summary of implementation?

The U.S. Department of Transportation launched the ICM Initiative in 2006, with the goal to begin initial research at several different pioneer sites throughout the country. The ICM pioneer sites are located in Oakland and San Diego, CA; Dallas, Houston, and San Antonio, TX; Montgomery County, MD; Seattle, WA; and Minneapolis, MN.

All eight cities participated in the ICM Initiative's phase one, which was completed in 2007 and consisted of developing concepts of operations and system requirements (Cronin et. al. 2010).

Phase two included the selection of San Diego and Dallas in 2012 to move into Phase 3 of the project, ICM deployment and evaluation. The ICM demonstrations in these two cities will consist of two phases: phase one encompassing design and deployment, and phase two being operations and maintenance. San Diego will implement ICM on its I-15 Corridor; Dallas will implement ICM on its US-75 Corridor. Results from these sites will be available in 2014 (RITA 2011).

The Sand Diego and Dallas ICM projects will collect information on the current travel conditions on freeways, frontage roads, arterial streets, High-Occupancy Vehicle (HOV) lanes, High-Occupancy Toll (HOT) lanes, and other modes of transit within the respective corridors. A decision support system (DSS) will help operators of the system to forecast corridor performance issues and select the appropriate combination of ICM strategies to apply to different operational conditions. A DSS allows transportation managers the ability to evaluate the optimum operational strategies and determine when and how to implement them. For example, operations personnel may adjust traffic signals and ramp meters to direct travelers to High-Occupancy Toll (HOT) lanes, bus rapid transit or perform other operations to improve roadway performance as needed. Operating agencies will share incident, construction, and special event information with each other through a common web interface so that transportation managers will be able to dynamically direct travelers to faster roadways or transit facilities (RITA 2011).

b. What policy mechanism was used?

The ICM demonstrations in San Diego, CA and Dallas, TX include partnerships between federal and local transportation agencies, as well as transit agencies.

The I-15 ICM Demonstration is a joint effort led by the San Diego Association of Governments (SANDAG) in collaboration with the U.S. DOT, California Department of Transportation (Caltrans), the Metropolitan Transit System, the North County Transit District, and the cities of San Diego, Poway, and Escondido (RITA 2011).

The US-75 ICM Demonstration is a collaborative effort led by Dallas Area Rapid Transit (DART) in collaboration with the U.S. DOT, City of Dallas, Town of Highland Park, North Central Texas Council of Governments (NCTCOG), North Texas Tollway Authority (NTTA), City of Plano, City of Richardson, Texas Department of Transportation (TxDOT), and the City of University Park.) (RITA 2011).

c. Results? Success? Uncertainties?

N/A

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

ICM corridors require multijurisdictional agency partnerships to collaboratively manage and control various multimodal systems. The current ICM project sites are collaborations between federal and local transit agencies. At the federal level, three USDOT agencies, RITA, FHWA, and the Federal Transit Administration (FTA) have partnered with the eight local pioneer sites to develop, deploy and evaluate ICM concepts and technologies (Cronin et. al. 2010)

b. What is the policy

The successful implementation of ICM requires careful strategic planning, a large integrated system, as well as advanced transportation analysis tools to estimate and predict travel system performance (Cronin et. al. 2010).

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

N/A

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Because ICM integrates a multitude of ITS technologies, public perceptions of overall ICM deployment will depend on their opinions toward each individual ITS strategy, i.e. ramp metering, traffic signal optimization, HOT lanes, etc.

b. Public issues / concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Traffic Signal Optimization

I) ***Brief Summary of the Strategy including history if appropriate to provide context***

Traffic signals are a vital component of our transportation infrastructure that helps control vehicular flow on surface streets. While traffic signals are an invaluable tool, they can have a multitude of negative impacts if not managed or timed properly. Poorly controlled traffic signals can cause abrupt acceleration and deceleration, increase stop-and-go driving, cause excess engine idling, and exacerbate traffic congestion; all of which can diminish vehicle fuel efficiency and increase greenhouse gas (GHG) emissions. With proper control and timing, traffic signals can be optimized to mitigate these adverse effects, promoting smoother flowing traffic and reduced GHG emissions.

Typically, traffic signals are optimized by coordinating the operation of many signals within a traffic corridor. Through signal coordination, it is possible to maximize green light time for vehicles traveling at the speed limit, and promote smoother flowing traffic. Such signal timing can be achieved with either static or dynamic control. With static operation, traffic signals operate under a fixed time schedule that controls the changeover from green to red lights, whereas dynamically controlled signals utilize real time traffic information to adjust the signal timing.

Other measures can also be taken to improve traffic signal operation. Unnecessary signals can be removed from intersections where they are not needed to promote smoother flowing traffic. Additional traffic detection systems can be installed on side streets, to better inform overall traffic signal timing. Traffic signals can also be equipped with more advanced control systems, enabling better communication between signals and allowing for control from a centrally managed location.

This literature review will focus on the impacts that signal coordination techniques can have on fuel use and GHG emissions.

II) ***Studies/Research***

a. *Quantitative range of GHG reductions or fuel savings*

In places where traffic signal optimization has been implemented, the literature shows measurable fuel savings and GHG reductions.

A study of coordinated traffic signals conducted within the metropolitan area of Phoenix Arizona, along the Scottsdale Road–Rural Road corridor, found that fuel consumption was on average reduced by 1.6 percent over all of the measured intersections. The effort involved a field evaluation of midblock travel counts, intersection turning movement counts, second-by-second speed measurements obtained from Global Positioning System (GPS)-equipped cars, and a modeling evaluation of the network impacts of traffic signal coordination. This study also found that the timed intersections promoted a 6 percent increase in speed along the main line over the a.m. peak, midday, and p.m. peak analysis periods, and reduced the number of vehicle stops by 3.6 percent (Rakha et. al. 2000).

A Parisian study found that an intersection equipped with a real-time adaptive signal control system known as CRONOS, led to a 3-4% reduction in GHG emissions. The CRONOS system is a real time traffic control algorithm, developed in France in the late 1990's, that utilizes video based measurements of queue lengths or spatial occupancy to coordinate traffic signals across multiple intersections (Boillot et. al. 2000). The study was performed over a period of 8 months at an intersection in the suburbs of Paris that experienced between 2,600 and 3,300 vehicles per hour. Utilizing video sensors to measure the speed and volume of local traffic going through the intersection, the study found that the CRONOS signalization decreased CO_2 emissions by an average of 8.8 lbs and 17.6 lbs (4 kg and 8 kg) per intersection per hour during off peak and peak hours respectively (Midenet et al., 2004).

In 2009, as part of the Clinton Climate Initiative, the City of Portland optimized traffic signal timing at 135 intersections on 16 different city streets. It was concluded that the optimization decreased fuel consumption by 1.75 million gallons of gasoline per year. This fuel savings translates to approximately 15,500 metric tons of CO_2 per year, or roughly 115 metric tons of CO_2 per intersection per year (FHWA 2012).

As part of the Fuel Efficient Traffic Signal Management (FETSIM) program, 41 California Cities retimed 1,535 traffic signals in 1983. Because follow-up field studies reported reduced vehicular delays and fuel consumption, the signal timing program was expanded over the next 11 years to retime 12,245 traffic signals in 160 California cities and counties. Throughout these areas it was estimated that fuel use was decreased by approximately 8% (Skabardonis 2001). In 1983, the first year of the program, efficiency benefits resulted in a reduction of 6.4 million gallons of fuel, equating to 56,898 metric tons of CO_2 annually and 37 metric tons of CO_2 per year per intersection (California Energy Commission 1984, FHWA 2012). Traffic and signal optimization techniques have improved significantly since this program was implemented so benefits using newer techniques may be higher (FHWA 2012).

A project in Northern Virginia that optimized 700 signals in Tysons Corner resulted in a reduction in fuel use between 10 and 12% (Whit et. al. 2000).

A study of signal optimization in Nashville, Tennessee found that retiming 223 signals along seven traffic corridors resulted in fuel use reductions of nearly 6% (Kimley-Horn and Associates 2006).

b. *Qualitative discussion about GHG reductions or fuel savings*

Traffic signal optimization is often undertaken to improve traffic flow, and reductions in GHG emissions are considered an added benefit. Through signal optimization it is possible to improve the operations, maintenance, timing, and location of traffic signals to promote smoother traffic flow, which results in reduced GHG emissions.

Estimates of reduced fuel consumption and emissions must be interpreted cautiously, because signal optimization may induce demand and reduce potential benefits. Induced demand is something that is not typically or clearly accounted for in the studies cited (FHWA 2012).

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

Yu and Recker (2006) refer to newer techniques (e.g., CRONOS or the Sydney Coordinated Adaptive Traffic System (SCATS)) that use real time data to "match" the current traffic conditions to the "best" pre-calculated off-line timing plan.

FHWA (2012) notes a variety of commercial modeling systems that can be used to determine delay, fuel consumption, and emissions from signalized intersections. They include SYNCHRO and TRANSYT-7F (for traffic flow), VISSIM-CMEN-VISCAOST (for scenario based fuel consumption), aaMOTION (a single vehicle software package for modeling fuel, emissions, and costs), PASSER II (measures cycle lengths in algorithm to estimate delay) and aaSIDRA (an intersection analysis software package). If changes in vehicular travel activity can be measured or modeled, EPA's MOVES model can also be used to estimate changes in emissions.

e. Uncertainties/qualifications to the data

The benefits of traffic signal optimization depend on a variety of factors, including the previous level of traffic congestion and the approach that was used to coordinate or optimize traffic signal timing. Thus, it is hard to generalize fuel savings estimates for all intersections that receive signal optimization.

There are additional uncertainties involved with analyzing traffic signal optimization. One short-coming is the effect of induced demand. If the optimization of a traffic signal were to reduce delays and congestion at a particular intersection, usage of that intersection might increase. Most studies do not explicitly take these effects into account, particularly if they only analyze intersection performance over a short-term time interval.

The effects of induced demand could be taken into account for a given area if historical traffic data were reviewed for a given intersection before and after traffic signal optimization was implemented. However, an analysis would need to take into account a variety of other factors, including changes in population, employment, fuel prices and the status of the nearby transportation infrastructure.

Another limitation of these studies is that estimates of fuel consumption are sometimes too simplified to accurately account for the wide array of vehicles in operation. Because emissions vary greatly between different makes, models, and ages of cars, the results of any model depend greatly on what assumptions have been made (Stevanovic, 2009).

III) **<u>Where has the strategy been implemented (if applicable)</u>**

a. Summary of implementation?

According to an FHWA report, traffic signal coordination and optimization systems have been implemented both in the United States and throughout the world. Typically, these systems are put in place to improve traffic flow and reduce congestion, rather than mitigate GHG emissions. Some specific examples listed include (FHWA 2012):

- Los Angeles (Sorenson et al. 2008);
- France (Midenet, 2004; Boillot 2000);
- Virginia (White, et al. 2000);
- Toronto, Canada (Greenough and Kelman 1999);
- California (FHWA 1995);
- China (Pandian, 2009; Li et al. 2004);
- Nashville, TN (Kimley-Horn and Associates. 2006);
- Florida (Stevanovic 2009); and
- Portland, OR (FHWA 2012)

b. What policy mechanism was used?

Discussed under section IV

c. Results? Success? Uncertainties?

N/A

IV) ***<u>Policy to Implement Strategy</u>***

a. *<u>In the United States, who would implement the policy (Fed, State, Local, agency, other?)</u>*

Traffic signal optimization is usually undertaken at the local and regional level and can involve the retiming of one particular intersection or the coordination of many signals across multiple intersections. MPOs typically coordinate the signal optimization projects, which are generally funded by DOTs. The upkeep and maintenance of the signal systems is usually the responsibility of local jurisdictions. When signal optimization projects span across multiple jurisdictions, many local agencies need to coordinate construction and maintenance of the systems (FHWA 2012).

b. *<u>What is the policy</u>*

Transportation and public works agencies utilize local, regional, state, and federal funds to implement traffic signal optimization programs. The costs for these programs include the purchase of new software and hardware (such as traffic detectors and new signaling equipment), the development of signal timing plans and management systems, as well as costs for maintenance and upkeep of the system. Typically, one of the major costs of implementing these projects is expertise to implement and maintain the traffic optimization plans, as intersections should be retimed every three years (FHWA 2012).

Recent estimates show that optimization of existing signals costs between \$2,600 and \$4,000 per intersection. Considering that traffic signals should be retimed approximately every three years, costs range between \$1,000 to \$1,300 per year per intersection. (Kittelson and Associates 2008).

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

N/A

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

Because signal optimization is usually undertaken to mitigate traffic congestion, it is likely to be supported by the public. However, as outlined below there may be some concerns regarding the technology.

b. *Public issues / concerns regarding the strategy*

While there would likely be little opposition to signal optimization programs due to the benefits of reduced congestion and shorter travel times, there may be some concern regarding the negative impacts on pedestrian / bike crossings. If signal optimization programs were to lead to longer green lights, there may be fewer opportunities for pedestrians / bikers to cross a given intersection. This may result in a reduction of safety for pedestrians, cyclists, and even drivers.

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Transportation Systems Management: ITS

I) Brief Summary of the Strategy including history if appropriate to provide context

Transportation systems management and operations (TSMO) refers to multimodal transportation strategies to maximize the efficiency, safety, and utility of existing and planned transportation infrastructure, such as (FHWA, 2012a):

- Traffic incident management
- Traffic signal coordination
- Transit signal priority and bus rapid transit
- Special event management
- Road weather management
- Managed lanes
- Parking management
- Electronic toll collection and transit smart cards
- Traveler information systems

While the primary goal of TSMO is to serve the mobility needs of people and freight and foster economic growth and development, it also has potential to provide energy and environmental benefits in terms of fuel savings as well as greenhouse gas (GHG) and pollutant emissions reductions. TSMO strategies are often enabled or supported by intelligent transportation system (ITS) technologies and applications.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

TSMO can help mitigate climate change by reducing fuel consumption and GHG, especially carbon dioxide (CO_2), emissions from vehicular traffic. Because TSMO encompasses a wide range of strategies, the range of fuel savings and GHG reductions that result from implementing these strategies can vary significantly. Some examples from literature are provided below:

- Modeling studies of coordinated signal control in 5 U.S. localities found reductions in fuel use ranging from no significant change in Seattle, Washington to a 13 percent decline in Syracuse, New York (U.S. DOT, 2008).

- Simulation of a transit signal priority system along a heavily traveled corridor in Arlington County, Virginia found a 2-3% reduction in fuel consumed by buses across a number of priority scenarios (Dion et al., 2002).

- A simulation study of the Minneapolis-St. Paul, Minnesota system found 2% to 55% fuel savings at individual ramp metering locations along two corridors that were modeled under varying levels of travel demand (Hourdakis and Michalopoulos, 2002).

- One study simulated different ramp control algorithms for a 16.2-mile stretch of freeway in Munich, Germany. It found that all control algorithms reduced fuel consumption by an average of 25% (Bogenberger et al., 2002).

- A simulation study for the San Antonio, Texas, region found that an implementation of travel information systems could decrease annual vehicle fuel consumption by 1.2% to 3% (Carter et al., 2000).

b. *Qualitative discussion about GHG reductions or fuel savings*

In general, there are three mechanisms through which TSMO strategies can reduce traffic-related CO_2 emissions (Barth and Boriboonsomsin, 2008).

- Mitigating congestion - Strategies that reduce severe traffic congestion such that higher average traffic speeds are achieved (e.g., ramp metering, incident management)
- Managing excessive speeds - Strategies that bring down excessive highway speeds to moderate speeds of approximately 55-60 mph (e.g., by speed limit reduction and enforcement)
- Smoothing traffic flow - Strategies that suppress shock waves and thus reduce the frequency and magnitude of acceleration and deceleration in stop-and-go driving (e.g., variable speed limits)

c. *Elasticities (if available)*

One recent study on the GHG impacts of a variety of transportation strategies used elasticities of travel with respect to total vehicle operating cost, which includes travel time, fuel costs, maintenance costs, and other out-of-pocket expenses. The elasticities of -0.4 for short-run and -0.8 for long-run were used for all transportation strategies studied including TSMO strategies (Cambridge Systematics, 2009). However, it was argued that these elasticities (or induced demand) were estimated from the effects of new transportation capacity (e.g., expanding existing roads or constructing new facilities). The induced demand from the effects of TSMO strategies could be much different, because while TSMO strategies improve travel times and reliability, they do not explicitly increase roadway capacity (Neudorff, 2010).

d. *Analytical tools for analysis (if available)*

GHG impact evaluation of TSMO strategies requires a combination of traffic and emissions modeling tools. Depending on the type of TSMO strategy being evaluated, the tools needed may vary. For traffic modeling of TSMO strategies, traffic microsimulation tools (Paramics, VISSIM, TransModeler, etc.) have generally been used as they are able to model detailed movements of individual vehicles in the traffic stream. This allows for the changes in individual vehicles' speed and acceleration due to TSMO implementation to be captured. For the modeling of TSMO strategies involving traffic signal optimization and coordination, specialized tools such as Synchro and TRANSYT-7F have also been used.

In terms of emissions modeling, tools such as MOVES and CMEM that are sensitive to modal vehicle operation (e.g., acceleration and idling) have been widely used. These emissions modeling tools are able to take the detailed vehicle speed and acceleration profiles generated by traffic microsimulation tools and estimate the corresponding vehicle fuel consumption and emissions on a second-by-second basis.

e. Uncertainties/qualifications to the data

The GHG benefits of TSMO not only vary by the type of strategy, but also depend on the following factors for the area it is implemented (Barth and Boriboonsomsin, 2008):

- Local fleet mix - Different fleet composition will cause different fleet-wide average CO2 emission factors. Therefore, the relationship between CO2 emissions and traffic speed would be different.
- Existing level of congestion - Different areas experience different levels of congestion and delay. Thus, the reduction in CO_2 emissions that could be achieved may be less in an area where congestion has not been much of a concern.
- Existing level of excessive speed travel - The amount of driving occurring at excessive speeds is also area specific, depending on several factors such as speed limit and enforcement. An area with a lower freeway speed limit is likely to have less CO_2 emissions than a corridor with a higher speed limit.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

TSMO strategies have been implemented across the U.S. and abroad. Examples of strategy implementations and their associated fuel savings and/or GHG reductions are provided below:

- California's Fuel Efficient Traffic Signal Management program optimized 3,172 traffic signals through 1998, and reported an average reduction in fuel use at these intersections of 8.6% for the program (Skabardonis, 2001).

- A study of signal optimization of 223 signals along seven corridors in Nashville, Tennessee found a fuel consumption reduction of nearly 6% along the seven corridors (Kimley-Horn and Associates, 2006).

- The Maryland CHART incident management program was estimated to save 4.84 million gallons of fuel on 20,515 incident clearances in 2005 (NTIMC, 2006). This amounts to approximately 235 gallons of fuel and 2 metric tons of CO2 saved per incident.

- Reductions in incident-related delays also lead to fuel savings and related emissions reductions. A benefit-to-cost analysis of Florida's Road Ranger service patrol documented a savings of 1.7 million gallons of fuel across the state in 2004 (Hagen et al., 2005).

b. What policy mechanism was used?

In most cases, TSMO strategies are implemented through traditional funding mechanisms. Transportation agencies program TSMO projects as part of their transportation improvement plans. However, there have been other innovative funding mechanisms as well.

For instance, since December 2002, The Climate Trust, a Portland-based nonprofit organization has contracted to buy carbon credits from a City of Portland project designed to improve the timing of traffic signals at congested intersections. The City's program costs were covered through a pay-for-performance contract with The Climate Trust, under which the nonprofit organization paid the City based on the amount of CO_2 emissions that were saved through the traffic signal optimization project. By October 2008, more than 157,000 metric tons of CO_2 were verified to have been saved (ITS America, 2010).

c. Results? Success? Uncertainties?

N/A

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Federal, state, regional, and local agencies all have a role to play in implementing TSMO strategies. TSMO implementation largely depends on the agency's jurisdiction, but multi-agency TSMO programs or projects are also common. For instance, traffic signal optimization is typically undertaken at the local and regional level. Metropolitan Planning Organizations typically coordinate signal optimization projects, while State Department of Transportations primarily provide funding, and local agencies implement and maintain the signals. Many local agencies may need to coordinate when signal optimization or coordination projects span multiple jurisdictions (FHWA, 2010b).

b. What is the policy

The policy for implementing TSMO strategies primarily involves securing funding and resources for engineering design, construction and installation, and operation and maintenance of the equipment, system, and/or technology.

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

In general, the political acceptance of TSMO is high. The Federal Highway Administration has a funding mechanism for TSMO programs. Also, several state and local agencies have already successfully implemented a variety of TSMO strategies.

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Most TSMO strategies bode well with the public as they provide perceivable improvements to the public's traveling experience. For instance, most drivers believed that traffic conditions worsened when the Minneapolis-St. Paul ramp metering system was shut down and 80% supported reactivation (Cambridge Systematics, 2001).

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Ramp Metering

I) <u>Brief Summary of the Strategy including history if appropriate to provide context</u>

Ramp metering is defined as the process of facilitating traffic flow on freeways by regulating the number of vehicles entering the freeway per interval of time through the use of control devices (most commonly traffic signals) on entrance ramps. The goal is to control the entry of cars onto the freeway in order to ensure proper spacing between vehicles is achieved and to limit the impact of newly merging vehicles on overall highway traffic flow. In general, most ramp meters across the country only operate during the a.m. and p.m. peak periods, although in very heavily congested areas there are some that operate continuously (Cambridge Systematics, 2001). Ramp meters typically allow freeways to accommodate a greater number of vehicles with fewer collisions and result in greater system reliability (TTI, 2007). In addition, ramp meters also tend to limit the number of entering vehicles onto a freeway by encouraging drivers to choose other streets for short distance trips in order to avoid the wait time at on-ramps (Cambridge Systematics, 2001).

Historically ramp meters have been employed on busy highway on-ramps to improve traffic flow and reduce overall traffic congestion by ensuring the roadway operates at or near its intended capacity. More recently, the effects of ramp metering on fuel use and emissions have become a topic of interest. It is posited that by metering or controlling the flow of traffic onto a freeway, ramp metering devices may serve to reduce overall fuel use and subsequently promote reductions in GHG emissions. However, vehicles idling at the ramp meters may also increase emissions.

Although ramp metering primarily serves to reduce traffic congestion and improve roadway safety, the following literature review will focus on the impact of ramp metering on fuel consumption and GHG emissions.

II) <u>Studies/Research</u>

a. <u>Quantitative range of GHG reductions or fuel savings</u>

The benefits of ramp metering to reduce GHG emissions are variable and uncertain. Some studies report that ramp metering increases CO_2 emissions, primarily because of increased idling at the on-ramp (Cambridge Systematics, 2001). However, other models and simulations report a net decrease in emissions, primarily from smoother traffic flows (Bae et al. 2012; Bogenberger et al., 2001; Piotrowictz and Robinson, 1995; Oregon DOT, 1982).

One recent study conducted by a group of South Korean researchers showed an overall decrease in CO_2 emissions as a result of ramp metering. The group used a 10.15 Km two-lane model of the Dong-Seo overpass (an area with heavy traffic congestion during peak hours) to estimate emissions before and after a locally controlled ramp metering device (allowing four vehicles every 30 seconds) was installed. The study showed that while the emissions of vehicles at on-ramps were increased, there was a 7.3% net reduction in overall CO_2 emissions (Bae et al. 2012).

A recent study by Cambridge Systematics of the Twin Cities region in Minnesota showed that ramp metering improved traffic volume, travel time, travel time reliability, safety, and particulate emissions on highways. Despite these positive outcomes, the report concluded that ramp metering resulted in higher annual fuel consumption from the higher vehicle speeds on highways and increased time idling at on-ramps (Cambridge Systematics, 2001). However, the report notes that it used a straight line estimation technique to calculate the increased fuel use, and explains that this model may not have adequately accounted for the tempering of flow typically brought about by ramp metering (which may reduce fuel consumption). The report did note that four other areas that instituted ramp metering systems estimated fuel savings ranging from 6 to 13 percent (Cambridge Systematics, 2001).

Another recent study simulated a variety of different ramp control algorithms on a 16.2 mile stretch of freeway in Munich, Germany. The study found that on average the different ramp metering control algorithms served to reduce overall fuel consumption by 26%, accounting for improved mainline flow and higher accelerations at the on ramps, while also significantly lowering emissions of NO_x, CO, and HC (Bogenberger et al., 2001).

DKS Associates conducted a study to analyze the potential traffic alleviation benefits of ramp metering in the San Joaquin valley. The report concluded through simulation that ramp metering would tend to increase mainline vehicle speeds by roughly 5%, and that overall there would be negligible fuel savings and GHG emissions reductions, finding only a 1 % improvement (DKS Associates 2001).

b. <u>Qualitative discussion about GHG reductions or fuel savings</u>

N/A

c. <u>Elasticities (if available)</u>

N/A

f. <u>Analytical tools for analysis (if available)</u>

Ramp meters typically employ fixed-time control strategies, allowing a vehicle to pass onto the freeway after a pre-determined time period (roughly 5 seconds) depending on prior traffic history and demand. In recent years, with the adoption of ITS technologies, ramp metering has begun to employ adaptive traffic-responsive algorithms, to control the entrance of vehicles onto highway systems. Increasingly, sophisticated system-wide adaptive ramp metering (SWARM) algorithms that account for real-time traffic conditions are being used, although these systems require a computerized connection to a control center that calculates adjustments in real time based on the given traffic scenario (Ahn, et al., 2007).

If one can accurately measure the changes in traffic volumes and flows affected by ramp metering, then EPA's MOVES model can be used to estimate changes in emissions (FHWA 2012).

g. Uncertainties/qualifications to the data

In general, most studies fail to fully characterize the change in GHG emissions due to ramp metering because of unintended consequences such as hard accelerations and induced demand. Thus the studies may or may not be completely accurate. The literature on the effects of ramp meters varies due in part to the differences in what is accounted for in the studies and simulations; for example some studies include idling at ramps, induced demand, increased traffic on local street networks, or increased speed on highways from improved traffic flow while others do not.

Based on the literature, ramp metering has been shown to affect fuel consumption and emissions in ways that are not often included in calculations or simulations, including:

- Increased fuel consumption from vehicles queuing at the ramp meters (stop and go);
- Higher accelerations are needed to enter the freeway after queuing ;
- General vehicular speed increases on the highway due to improved traffic flow;
- Life cycle emissions from required on-ramp improvements (e.g., ramp striping) that are needed to take full advantage of the effectiveness of the meters (DKS Associates, 2008); and
- Induced demand from reduced highway congestion.

As a result, the effectiveness of ramp meters as a GHG mitigation strategy is to some degree unknown (FHWA 2012).

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

Use of ramp meters is common and widespread throughout the country and the world, especially in larger metropolitan cities. However, the purpose of ramp meters is to improve traffic flow rather than decrease emissions or fuel consumption. According to the FHWA 2012 report some specific examples of documented ramp metering include:

• Minnesota (Twin Cities)(Cambridge Systematics et al., (2001); Levinson, et al., 2006);
• Madison, WI (Kim et al., 2004);
• Denver, Colorado (Kim et al., 2004);
• Portland, Oregon (Ahn et al., 2007; Kim et al., 2004);

• Seattle, WA (Kim et al., 2004);
• Los Angeles, CA (Ahn et al., 2007; Sorensen, 2008);
• Seattle, WA (O'Brien, 2000); and
• Atlanta, GA (Guensler et al., 2001).

As noted previously, the primary purpose of the above implementations was to mitigate traffic congestion, rather than mitigate greenhouse gas emissions. As a result, most studies have relatively limited evaluation of the ramp meters' effect on fuel consumption.

b. *What policy mechanism was used?*

N/A

c. *Results? Success? Uncertainties?*

N/A

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

Ramp meters may be installed by local/municipal, regional MPO, and state transportation agencies. Most ramp metering systems have been implemented by partnerships between state and regional/municipal agencies. (FHWA 2012)

b. *What is the policy*

Ramp metering is completed by installing detection and signaling devices at the on-ramp entrance to a freeway. The ramp metering device can either utilize a fixed-time control strategy, one that allows a vehicle to pass onto the freeway after a pre-determined time period (roughly 5 seconds) depending on prior traffic history and demand, or it can utilize an adaptive traffic-responsive algorithm to control the ramp metering based on real time traffic conditions.

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

The barriers to the implementation of successful ramp metering are the perceived inequities as well as the perceived delay increases. Although it has been shown that ramp metering usually decreases the incidence of traffic congestion on the primary road, the public generally feel that ramp metering leads to greater delay while waiting to enter the primary road. As a result, politicians may be wary to support a ramp metering device because of negative public perceptions. In addition, ramp metering tends to benefit travel times for long distance trips more so than it does for short distance trips. As a result, this inequity could result in some political reservations to instituting the technology.

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Ramp metering can be potentially expensive, depending on the infrastructure and technology improvements needed to implement the ramp metering system. In general, the public may oppose ramp metering systems due to increased delays at the ramp and perceptions of trip inequity.

Initially, ramp metering implementation is typically opposed by the public because of increased queues at on-ramps (FHWA, 2006). There is also believed to be undesirable levels of traffic diversion to surface streets, as well as increased emissions and fuel consumption at the ramps themselves (Pearson et al., 2003). In addition, equity issues may arise due to the fact that ramp metering often benefits longer trips rather than shorter ones (Pearson et al., 2003).

Education campaigns targeted at informing the public of the benefits of ramp metering have helped public acceptance. However, even after being educated of the benefits of ramp metering the public still believes that there is too much metering (Gordon 2009).

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

The cost of a particular ramp metering system varies widely in accordance with the sophistication of the algorithm used to set the metering rate and the number of ramps included in the system (Pearson et al., 2003). Therefore the cost to mitigate GHG emissions using ramp metering is difficult to calculate.

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HOV Lanes and Ridesharing

I) *Brief Summary of the Strategy including history if appropriate to provide context*

According to the 2001 National Household Transportation Survey, over 85% of all trips in the U.S. were made by car, and 65% of those trips were made in single-occupancy vehicles (SOVs) (FHWA 2012). Because a majority of commuter trips are taken in single-occupant vehicles, it is possible to expand the capacity of existing roadways, limit traffic congestion and reduce GHG emissions by increasing vehicle occupancy. Ridesharing and High Occupancy Vehicle Lanes (HOV) are among a subset of transportation demand management (TDM) strategies designed to reduce the demand for roadway travel, particularly for SOVs.

The primary goal of HOV lanes, commonly referred to as car-pool lanes, is to move more people on the highway system rather than move more vehicles. According to the California Department of Transportation, some HOV lanes carry nearly half of the people traveling on a freeway (CADOT 2013). Typically HOV lanes are added as an extra lane onto pre-existing roadway systems, rather than converting existing lanes. In order for travelers to take advantage of an HOV lane, they must have the minimum number of people posted on the lane's entrance sign, typically two or three occupants. However, there are exceptions to this rule. For example, motorcycles are allowed access to the HOV lanes, even if they are carrying only a single person. In addition, vehicles that meet specified emission standards may be afforded access to the HOV lanes, even with a single rider. In California, these vehicles are issued "Clean Air Vehicle"(CAV) stickers that allow the vehicle with a single occupant access to the carpool lanes at all times (CA DMV 2013). According to the California Air Resources Board, nearly 14,000 such stickers have been issued in the state of California as of May 1st 2013 (CA EPA 2013). Typically these stickers are awarded to "zero emission vehicles" (ZEV), "advanced technology partial zero emission vehicles" (ATPZEV), or vehicles referred to as "super ultra-low emissions vehicles" (SULEV) that are 90 percent cleaner than the current average year's models.

Ridesharing strategies and services are also designed to increase vehicle occupancy and ridership, typically by encouraging carpooling or vanpooling on a voluntary or prescriptive basis. Recently there have been a number of developments in what is called "peer to peer ridesharing," a system that utilizes the internet and smartphones to connect users to share vehicle trips and costs on a voluntary basis. Ridesharing firms, including Lyft, Uber and SideCar, have grown in popularity and use in recent years, with the company Lyft claiming that nearly 30,000 people use its application per week to match drivers and riders together (SF Gate 2013). While these applications may further promote the use of ridesharing, they face serious opposition from taxi and driver services, and still need to fully resolve applicable liability and insurance concerns.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

According to the Washington State Department of Transportation, HOV lanes move nearly 35% of the people on rush hour freeways in approximately 19% of the total vehicles (Washington State DOT 2013). These percentages may be higher in other states, as the California Department of Transportation reports that some HOV lanes carry nearly half of the people traveling on a freeway (CADOT 2013).

A study of ridesharing and carpooling in the city of Atlanta found a reduction of 8,170 trips and a net reduction of 218,000 vehicle miles traveled (VMT) per day (CTE 2002). A subsequent evaluation by the Georgia DOT found that a variety of ridesharing based measures were estimated to eliminate 41,000 vehicle trips daily, and 885,000 VMT (CTE 2004). To put these numbers into GHG reduction terms, if one were to assume that the displaced trips noted above took place in cars and light trucks (average fuel economy of 20.7 mpg), then the daily 885,000 VMT reduction would result in a reduction of 380 metric tons CO_2 (FHWA 2012).

A recent study examined the potential energy and fuel impacts of casual carpooling. Casual carpooling, also known as “slugging,” is a system where riders queue at designated pickup points, in the early morning and late afternoon, as if waiting at a taxi stand. Drivers pick up the appropriate number of carpoolers to provide them access to the HOV lane, and drop riders off at a predetermined destination. Minett (2011) estimated that casual carpooling in San Francisco conserves between 1.7 and 3.5 million liters of gasoline per year. This is equivalent to 0.45 to 0.92 million gallons of gasoline saved annually, with emission reductions ranging between 4,000 and 8,335 metric tons CO_2. The paper concludes that further catalyzing the existing system in San Francisco and other cities could serve as a means of reducing transportation energy use and GHG emissions.

Another study found that casual carpool systems in the San Francisco Bay Area and in northern Virginia -- systems that account for 3,000 and 3,500 carpools per day, respectively -- save nearly 3 million gallons of gasoline per year and reduce emissions by approximately 27,000 metric tons of CO_2. The report estimated that a group of 150 commuters who switched from SOV commuting to casual carpooling would save almost 52,000 gallons of gasoline per year. This data was based on assumptions of 12 mile commutes, and HOV lanes that had smoother flowing traffic at higher speeds than the conventional general purpose lanes (Dorinson et al., 2009).

In contrast, a study that modeled the conversion of existing HOV lanes back to general purpose lanes in the city of Minneapolis, found a savings of 4,000 gallons of fuel per day due to an increase of average speeds throughout the region (Cambridge Systematics and URS, 2002). This could correlate to an emissions reduction of approximately 36.2 metric tons CO_2.

One study that explored the theoretical fuel savings from increased ridesharing in the United States concluded that if one additional occupant were added for every 100 vehicles on the road, 0.80 – 0.82 billion gallons of gasoline could be saved annually. If one additional passenger were added for every ten vehicles on the roadway, the annual fuel savings would be 7.54 – 7.74 billion gallons, approximately 5.4% of the fuel consumed annually by cars and light trucks (Jacobson and King 2009).

A recent overview of literature on HOV lanes and resulting emissions concluded that there was a "lack of in-depth information on the air quality, energy, and other related environmental impacts of HOV facilities" (Turnbull et al., 2006).

b. *Qualitative discussion about GHG reductions or fuel savings*

Although ridesharing trends in the United States are fairly well documented, there is little information regarding the particular effects of ridesharing promotion. A driver's willingness to participate in ridesharing can be influenced by a multitude of factors, which may include the relative cost of SOV driving versus carpooling, distance to work, level of education, type of employment, gender and household size (Parkany 1998). It is also important to note that a large portion of carpooling studies rely on commuter surveys rather than on observed behavior.

In addition, the effect of ridesharing on GHG emissions can vary greatly depending on the policies in place to promote ridesharing, as well as the context in which it is promoted. Because a majority of ridesharing studies report vehicle occupancy rates rather than GHG emissions, it is difficult to make generalizations regarding the direct impact on GHG emissions (FHWA 2012).

The impact of HOV lanes on GHG emissions are also difficult to quantify, as studies do not typically assess GHG emissions directly. In addition, some HOV studies have reported increases in ridesharing as a result of HOV lanes, while others have not shown an increase (FHWA 2012). Studies comparing HOV lanes to general purpose lanes have mixed results. Dahlgren (1998) found that HOV lanes are superior to general purpose lanes only under two conditions: (1) there is a substantial travel time differential between the HOV lane and the general purpose lanes, and (2) the HOV lane is well utilized, which requires both a high proportion of HOVs and a high volume of traffic.

From a life cycle perspective, it is important to note that the construction and creation of new HOV lanes produces GHG emissions. It is therefore important to include these impacts when measuring the effectiveness of HOV lanes as a GHG mitigation strategy.

GHG reductions from increased ridesharing and HOV lane use are also highly dependent on vehicle technology and trip type. For example, reducing the use of a vehicle with low fuel economy would have a greater effect on emission reductions than reducing the use of a vehicle with high fuel economy. This relationship implies that ridesharing strategies have a diminished effect when coupled with higher fuel economy standards, fuel improvements, and system efficiency improvements. In addition, according to the National Household Travel Survey conducted in 2001, the average vehicle occupancy for work trips was 1.13, while for social trips it was 2.03; the average for all trips was 1.63 (Hu and Reuscher 2001). This implies that ridesharing strategies may result in greater benefit if programs are targeted at increasing vehicle occupancy for trips with higher use of SOV, in this case work trips.

c. *Elasticities (if available)*

While HOV lanes may be a factor that affects an individual's decision to rideshare, the extent of this is unknown and depends on many different factors. An FHWA report found that HOVs have a mixed record of promoting rideshare formation and that relatively little information on emissions impacts is available. In terms of emissions, older studies from the 1970s estimated reductions in fuel consumption ranging from 7-10% to up to 26% (FHWA 2012).

d. Analytical tools for analysis (if available)

N/A

e. Uncertainties/qualifications to the data

The greatest uncertainty in estimating the effects of ridesharing is the degree to which SOV drivers respond to ridesharing incentives as well as the availability of HOV lanes.

It is also difficult to account for ridesharing's effects on induced demand. Although some drivers may switch to ridesharing programs and limit their SOV use, their switch may open up new space on highway systems and make driving a more attractive option to people who did not previously utilize SOVs for their trips. As a result, it is possible that some of the GHG reductions initially brought about by ridesharing strategies could be offset to some degree or wholly negated by induced demand.

To address the issue above it is important to make the distinction between "carrot" and "stick" based incentive ridesharing programs. "Stick" based strategies, such as road pricing as well as parking pricing and management are typically more effective at encouraging people to reduce SOV driving, and are generally immune to induced demand because they increase the cost of driving for everyone. "Carrots" or transit incentives such as transit improvements, HOV lane access, and reduced highway tolls provide useful alternatives to limit SOV use, and should be utilized in tandem with "stick" based strategies to improve the overall effectiveness of ridesharing strategies.

There is also uncertainty regarding the relationship between cause and effect, meaning it is hard to determine whether or not people carpool more frequently because they prefer to drive less, or whether a ridesharing program encouraged them to drive less. For example, does ridesharing cause its members to drive less, or do people who already prefer to drive less participate in these programs? As a result, self-selection may tend to limit the overall effectiveness of ridesharing and HOV lane strategies.

There are other unintended effects associated with ridesharing that are typically disregarded by most studies. For example, although each ridesharing trip may remove one or more vehicles from the road, the vehicle that is being used must likely travel farther to pick up and drop off each passenger. Such side trips may diminish GHG emission reductions.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

HOV lanes of various types (full-day vs. prescriptive hours, reversible vs. permanent, etc.) have been built in 25 states as of 2007 (FHWA 2012). In general, most or all HOV lanes enable ride sharers to avoid congestion and sometimes tolls by designating specified lanes off-limits to SOVs. The number of occupants required in order to use HOV lanes varies from region to region. Sometimes two people are required to enter the carpool lane, sometimes three. The time of day that the lanes are restricted can also vary; some operate during peak hours only, others operate 24 hours a day.

In terms of ridesharing, most metropolitan regions have a commuter assistance program whose function is to decrease SOV commuting within that region. These programs generally work with employers to encourage employees to limit SOV use in their daily commute and some also provide rideshare matching services for the employees. Many also conduct general outreach and information campaigns through media outlets and special promotions ("walk or bus to work week") to raise the public's awareness of commuting options. In three regions—Seattle, Southern California, and Tucson—employer trip reduction programs are mandatory; in other areas they are voluntary (FHWA 2012). Casual carpooling has been shown to take place in the San Francisco Bay Area; Washington, D.C.; Houston; and Pittsburgh (Kelley 2007). Peer to peer ridesharing programs exist throughout the country, but are more concentrated in highly developed metropolitan areas.

b. What policy mechanism was used?

Ridesharing, or carpooling, can occur without the passage of any major policy or legislation, as riders can simply choose whether or not to drive with one another. However, there are certain policies and programs that can be implemented to further promote ridesharing behaviors.

Typically ridesharing is divided into carpooling, in which ride sharers use their own personal vehicles, and vanpooling, in which employers provide group transportation in larger vans and buses. Most efforts to increase participation in carpooling and vanpooling are made at the regional level by commuter assistance organizations. One strategy often utilized is rideshare matching services, which allow prospective ride sharers the ability to find others who live and work near them. Many firms also provide "dynamic ridesharing," which makes quick matches online for one-time rides, rather than arranging rides over an extended period of time. Employers can also encourage carpooling by offering preferred parking or cheaper parking rates for carpoolers. In some regions these sorts of programs are mandatory; in others providing alternatives to SOV transportation by offering ridesharing services is at the discretion of the employer.

"Casual carpooling" can also take place without specific legislation. Drivers and passengers who participate in casual carpooling generally agree to a few rules, which tend to be self-enforced, and safety has not proven to be a major issue with these programs (FHWA 2012). If local governments wish to encourage "casual carpooling", they may assist such programs by installing signage to help designate pickup and drop-off zones.

In some regions, high-occupancy vehicle (HOV) lanes can be constructed to encourage ridesharing. HOV lanes can be converted from traditional lanes, or built as entirely new lanes. HOV lanes are intended to benefit those who carpool by providing smoother flowing traffic, designated off ramps, as well as lessened or no toll cost at all. Typically HOV lanes are constructed as additional lanes, so as to not disrupt / limit flow in the existing lanes.

c. Results? Success? Uncertainties?

One report in California, which has more HOV lanes than any other state, found that a number of carpoolers in the San Francisco Bay Area cited the existence of HOV lanes as a factor in their decision to carpool. In Southern California, the creation of HOV lanes resulted in an increase of carpooling / ridesharing behavior of 25 to 35% in the peak period carpool lanes; roadways without HOV lanes experienced either no change, or a decrease in the number of carpools. (FHWA 2012). This suggests that the construction of HOV lanes can increase ridesharing and carpooling behavior.

An evaluation of the HOV lanes in Southern California found that about half of all carpools using the HOV lanes were formed in response to the HOV lane, and that average vehicle occupancies increased on the facilities with HOV lanes compared to two control routes (Parsons Brinckerhoff Quade and Douglas et al. 2002).

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Public agencies, such as State Departments of Transportation and local transit agencies, construct, operate and maintain HOV lanes, often with federal funding and support. Some municipal transportation agencies have built HOV facilities on local roadways, and in California, a private company has built a toll road on State Route 91 that serves carpools (FHWA 2013).

Most efforts to increase carpooling and vanpooling are made at the regional level by commuter assistance organizations (FHWA 2012).

b. *What is the policy*

N/A

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

For ridesharing programs, there are few concerns; these programs are widely implemented and well accepted given the benefits that they provide to travelers (FHWA 2012).

For HOV lanes, there is concern that they may take away capacity from SOV driving and result in greater levels of traffic congestion. HOV lanes may also involve construction costs if new lanes are to be created, which may result in higher costs than other TDM strategies (FHWA 2012).

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

Ridesharing generally occurs without any policy intervention, since many people are willing to share rides for cost savings, company, and convenience.

For HOV lanes, the public is generally concerned that they may take away capacity from SOV driving and result in more highway traffic overall. As a result, there has been an increase in the number of high-occupancy toll (HOT) lanes, which are thought to be a more effective means of managing traffic demand. The construction of HOV lanes may also create traffic delays during the period of construction, as general purpose lanes may need to be periodically closed. These closures can result in delays that would likely hurt public acceptance of the strategy.

The public is typically not in favor of increased transit fees aimed at reducing SOV driving. These "stick" based policies tend to be economically controversial because they add to a driver's business or household expenses, and these expenses may be in various regards inequitable. These concerns are most important in the context where drivers have few or no alternative options to SOV driving available to them. Value pricing based strategies are also frequently opposed because higher toll rates are considered as a new tax on riders.

Conversely, making alternatives to SOV driving less expensive is typically found to be socially acceptable, because choosing those alternatives is a voluntary choice and no undue burden is placed on those who still choose to drive.

b. Public issues / concerns regarding the strategy

Ridesharing on a voluntary basis is already a widely accepted strategy. While several regions have passed ordinances that require employers to provide ridesharing options, these tend to be more controversial. Los Angeles was one such city that had fairly stringent requirements to promote ridesharing before pressure from the business community resulted in their softening.

Although generally accepted HOV lanes have met with controversy as well, because they are perceived as taking capacity away from SOV drivers, thereby negatively contributing to traffic congestion. HOV lanes are also sometimes questioned from an environmental perspective, because some feel that freeing up capacity on the roadway induces more travel demand for driving (Turnbull et al., 2006).

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N.A

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Air Traffic Ground Operations

I) ***Brief Summary of the Strategy including history if appropriate to provide context***

Air travel has experienced rising demand, leading to environmental concerns regarding traffic, technologies, and procedures for both air and ground operations. Air transport accounted for 2.5% of global CO_2 emissions from fossil fuel use and 11% of worldwide transport CO_2 emissions in 2008, and these numbers are expected to rise as service demand at airports increases. These stresses on air travel are most apparent in large commercial airports within major metropolitan areas, and the impacts extend to ground-level operations on nearby highways and roads (Yu et al., 2003). Improved operations pertaining to aircraft communication systems, navigation systems, and flight paths can mitigate the greenhouse gas (GHG) and fuel effects of air traffic operations, but require international coordination due to the transnational nature of air travel. The U.S. will likely play a key role in these efforts since 16 of the world's top 25 airports are located within the U.S. (Ang, n.d.).

Airport facilities alone can significantly reduce GHG and fuel consumption through the implementation of ground-level strategies that facilitate efficient passenger, freight, and employee movement to and from airports. Measures can also reduce energy and waste consumption at airports, which are not necessarily related to traffic operations but are nonetheless tied into overall plans to meet emission reduction goals at airports over the next few decades. These long-term comprehensive strategies are articulated in the Climate Action Plans (CAPs) of U.S. international airports such as San Francisco International Airport, although not all major airports have made such documents available. While energy and fuel efficiency of airports include both air- and ground- level operations, this literature review will focus primarily on ground-level operations occurring in and around airports, as well as the diversity of strategies implemented in order to mitigate the impacts.

II) ***Studies/Research***

a. *Quantitative range of GHG reductions or fuel savings*

Yu et al. (2003) report significant daily, weekly, monthly, and yearly CO_2 traffic emissions from ground-transport at the Intercontinental Airport of Houston (IAH), although they do not mention corresponding fuel and GHG savings for any strategies implemented at IAH. In the year 2002, they found that 52,052.40 g of CO_2 were emitted within a 1-day period, with a majority of CO_2 emissions occurring between late morning and early night. Within a 1-week period, they reported 271,895.51 g of CO_2 being emitted from IAH. Within a 1-month period in August, they reported 1087.58 kg of CO_2 being emitted. Finally, within a 1-year period in 2002, they reported 13,050.98 kg of CO_2 being emitted. The numbers that Yu et al. report are useful for estimating and evaluating air quality due to its specificity and accuracy.

San Francisco International Airport (SFO) (2013) has looked extensively into numerous mitigation measures for ground transport and the extent of annual savings for each proposed strategy. GHG emission mitigation measures helped reduce 41,816 tonnes of GHG in 2010, 62,381 tonnes of GHG in 2011, and 69,776 tonnes of GHG in 2012. Specific GHG emission mitigation measures related to transportation include the Green Car Incentive Program that reduced 8,046 tonnes of GHG in 2012, use of SFO's BART extension that offset 2,415 tonnes of GHG in 2012, and use of SFO's Airtrain Facility that offset 2,120 tonnes of GHG in 2012. GHG emission offset measures helped offset 2,205 tonnes GHG in 2010, 2,619 tonnes of GHG in 2011, and 2,852 tonnes of GHG in 2012. However, these measures include strategies such as waste recycling and tree planting. Fleet vehicle replacement strategies also reduce GHG emissions, and such measures can annually reduce emissions between 130 and 225 tons.

b. Qualitative discussion about GHG reductions or fuel savings

According to Airports Council International (2009), GHG mitigation strategies come from three major sources: airport operators, aviation, and ground transportation. For airport operators, emissions reductions can be achieved from modernization of power, heating, and cooling systems, design of "smart" energy efficient buildings, modernization of fleet vehicles, driver education on fuel conserving driving techniques, and waste management. In terms of aviation, emissions reductions can be achieved from improved taxiway, terminal, and runway configurations, as well as modernized departure and arrival management systems. For ground transportation, emissions reductions can be achieved from the provision of public transport and rapid transit, educational campaigns to reduce vehicle idling, hotel and rental car agency shuttle bus consolidation, encouragement of alternative fuel or hybrid vehicles, and provision of fuel/power infrastructure for low-emission vehicles.

c. Elasticities (if available)

N/A

d. Analytical tools for analysis (if available)

According to Yu et al. (2003), the current urban transportation planning process does not adequately address the traffic and emission problems for airports since airports are treated as a special generator in terms of overall travel demand forecasting and emissions estimation. There are many traffic simulation programs that look at urban roadway and freeway traffic, but traffic around airports displays unique driving behavior, operation characteristics, and parking activities. A simulation model that can best capture the conditions at airports should consider car following behavior, vehicular specific characteristics such as acceleration and deceleration, distribution of speed at which vehicles drive through a terminal, distribution of arrival time at an airport, and distribution of waiting time inside an airport.

e. Uncertainties/qualifications to the data

N/A

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

As demonstrated in *Section IIa.*, one of the most comprehensive and successful strategies for achieving reduced GHG emissions for ground-level airport operations is SFO's annually updated Climate Action Plan. In 1990, SFO generated an estimated 50,128 metric tons of GHG from airport operations, and Ordinance 88-01 subsequently mandated SFO to not allow GHG emissions to exceed 37,596 tons per year by 2017, 30,077 tons per year by 2025, and 10,026 tons per year by 2050. To meet the goals of the new ordinance, SFO developed mitigation, offset, and reduction measures to lower GHG emissions by 40% before 2025, and identified both direct and indirect sources of emissions in the process. Some of these strategies were transportation-related, including the replacement of SFO's vehicle fleet with electric vehicles, CNG vehicles, and more energy efficient biodiesel vehicles, as well as transit initiatives for employees. Other strategies such as facility energy use reduction and zero waste plans, while not transportation-related, contribute to the airport's ability to meet GHG emission reduction goals. SFO also developed a Transit First Policy that promoted high occupancy vehicle (HOV) access to airports, regional transit services such as rail and ferry, preferential parking for employee vanpools, and efficiency of airport roadway and ground transportation loading zones. Specific strategies that emerged from the Transit First Policy included a Bay Area Rapid Transit (BART) SFO Discount Card for airport employees, more frequent service by the San Mateo County Transit (SamTrans) District Public Bus Service, direct terminal access by ground transportation vehicles to SFO to encourage shared-ride modes, and curbside management programs to improve customer service and traffic flow (San Francisco International Airport, 2013).

Other airports in the U.S. and Europe have developed measures for reducing emissions, although it is unknown if the plans are outlined in a document such as SFO's Climate Action Plan. In the U.S., MacAbrey (2009) notes that Oregon's Portland International Airport replaced a fleet of ground-support vehicles with alternative-fuel vehicles, the Los Angeles International Airport built the first airport-based retail hydrogen-fueling and generation station, and Boston's Logan International Airport set aside 100 parking spaces for hybrid and alternative-fuel vehicles in response to 2007 Earth Day. In Europe, airports such as the Stockholm-Arlanda Airport have received tremendous public support for programs to minimize costs and attain energy independence and have thus undertaken measures such as "eco-taxis" that run on separate lines from other taxis in and out of the terminal. In fact, MacAbrey states that the key difference between European and U.S. approaches to airport GHG emission strategies is that Europe has traditionally prioritized public transportation to airports, and that cities such as Athens, Hamburg, London, and Paris have provided more extensive alternative transport modes for passengers and airlines/airport staff.

b. What policy mechanism was used?

N/A

c. Results? Success? Uncertainties?

SFO's fleet vehicle replacement strategy is expected to replace 234 out of 354 vehicles over a six-year period and reduce GHG emissions by 528 tons per year (San Francisco International Airport, 2013).

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Based on the SFO Climate Action Plan (2013), the city and/or county in which the airport is located often leads the effort to reduce airport-related GHG emissions. Ordinance 81-08, which set long-term GHG reduction goals for SFO, was adopted by San Francisco's Board of Supervisors and signed into law by San Francisco's Mayor. SFO's mayor-appointed Airport Commission was also a key advocate for climate change initiatives and developed the Climate Action Plan in 2008 that served as blueprint for future developments in accordance with Ordinance 81-08. Unlike air-level operations such as flight paths and air communications systems that are developed on the federal level by the Federal Aviation Administration and often times coordinated on the international level, it appears that the implementation of GHG strategies are more locally and/or regionally based.

b. What is the policy

N/A

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

N/A

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

In Europe and in Stockholm in particular, environmental programs at airports are generally supported by the public since these strategies are not just tied to CO_2 reduction but also to cost minimization and energy independence (MacAbrey, 2009). In terms of employee acceptance and resistance to transportation-related environmental measures at airports, the SFO Climate Action Plan (2013) reveals that 76 percent of employees continue to drive alone to work, 11 percent of employees use some type of vehicle-pooling, and 12 percent of employees utilize public transit. Employees have cited travel time and convenience as the most important factors in determining commute mode, which makes single occupancy vehicle driving to airports the most time-efficient option for a majority of commuters based on the SFO survey.

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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APPENDIX C

CONSTRUCTION

LITERATURE REVIEW

Construction Materials

I) Brief Summary of the Strategy including history if appropriate to provide context

The production of pavement and bridge materials accounts for the majority of energy used to produce transportation construction materials (Zapata and Gambatese, 2005). Cement, and asphalt production in particular, is one the largest sources of industrial process-related carbon dioxide (CO_2) emissions in the United States. For example, U.S. cement production emitted approximately 31.6 million metric tons of CO_2 in 2011, which is about 10% of CO_2 emissions from industrial processes and about 0.5% of all CO_2 emissions for the year (U.S. EPA, 2013).

Transportation agencies are beginning to use alternative construction materials in order to decrease the adverse effects of construction on the environment. The most common forms are the use of fly ash and slag in concrete mixture, the use of warm- or cool-mix asphalt instead of hot-mix asphalt, and the use of recycled materials in pavement and bridge construction.

- *Fly ash and slag*: Fly ash and slag are two main materials that are commonly used to replace Portland cement in concrete mixture. Fly ash is a waste product of powdered coal after being burned in power plants. Slag is a waste product from the blast furnace production of iron from ore. Since the manufacture of cement consumes an enormous amount of energy and releases substantial quantities of CO_2, replacing cement with alternative materials helps reduce the carbon footprint of the concrete.

- *Warm-mix asphalt*: New technologies have been developed to lower the mixing and placement temperatures of asphalt pavement. These technologies are generally referred to as warm-mix asphalt (WMA), which uses less energy and produces less CO_2 than the traditional hot-mix asphalt during production and placement.

- *Recycled materials*: Recycled aggregates are produced from previously used pavement materials such as concrete and asphalt and are commonly used as a base layer for pavement construction in the U.S. Recycled asphalt also shows promise in reducing production and construction energy requirements (Miller and Bahia, 2009). Other recycled materials that can be used in road construction include rubber tires and shingles for asphalt pavement as well as glass, wood ash, and paper mill residuals for concrete production (Naik and Moriconi, 2006).

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

There are several examples of agencies using alternative construction materials, but few research studies specifically calculate the energy savings and GHG reductions from using these types of construction materials. Moreover, energy savings and emissions reductions from the use of alternative materials vary depending on type of material, percent of recycled content, the scope of project, and other factors.

- *Fly ash and slag*: Concrete used in highway construction typically consists of 10-15% Portland cement. Replacing Portland cement with fly ash or slag can significantly reduce CO_2 emissions. It is estimated that every ton of fly-ash substituted for Portland cement reduces life-cycle CO_2 emissions by almost one ton (Estakhri and Saylak, 2005). Using concrete mixture with 30% fly ash when replacing the current highway system over 20 years could yield 14 million metric tons of CO_2 reductions (Sullivan, 2006). The same amount of reduction can be expected from replacing Portland cement with slag.

- Warm-mix asphalt: Using warm-mix asphalt instead of the traditional hot-mix asphalt can reduce energy consumption and CO_2 emissions during the mixing process by 15-35% while half-warm mix and cold-mix asphalts can reduce energy consumption and CO_2 emissions by 50% (D'Angelo et al., 2008). Another study reports that warm-mix asphalt reduces CO_2 emissions by about 9 kg per ton of aggregate (Olard and Romier, 2008). If warm-mix asphalt replaced all traditional asphalt construction in the U.S. for future construction and maintenance projects, approximately 5 million tons of CO_2 emissions would be reduced annually (D' Angelo et al., 2008).

- Recycled materials: In an Australian study, recycled aggregates take 46% less energy (and thus reduce GHG emissions) to produce than new aggregates. In addition, there are potential savings in energy and emissions associated with transporting materials, especially where recycled materials are reused in close proximity to the site of reprocessing (SASA, 2013).

b. Qualitative discussion about GHG reductions or fuel savings

There are potential indirect CO_2 reductions from using concrete mixtures with high slag content. These concrete mixes are found to have higher solar reflectivity than the conventional mix with no cement replacement, which helps reduce urban heat island effect in urban areas. Research has shown that a concrete mix with 70% of the cement replaced by slag has 71% higher solar reflectivity than the conventional mix while achieving necessary mechanical properties for use in highway pavement applications. Using this high solar reflectance concrete for roads, parking lots, and sidewalks could reduce the mean air temperature in large U.S. cities by 0.2 to 0.7 degree Fahrenheit, which translates into a substantial amount of energy savings and CO_2 reduction by reducing cooling needs in buildings (Boriboonsomsin and Reza, 2007).

c. Elasticities (if available)

N/A

h. Analytical tools for analysis (if available)

N/A

i. Uncertainties/qualifications to the data

The type of alternative construction materials used as well as the materials they are replacing can vary the energy use and GHG emissions of the construction. Also, a comprehensive analysis of the reduction should account for life-cycle energy use and GHG emissions from the production of the materials to the transport of the materials to the site to the mixing and using the materials in the construction. For instance, due to the nature of fly ash and slag as an industrial by-product, there is no primary cost to its production (because it would be produced regardless of the needs of transportation construction). However, the transportation of fly-ash and slag from source to site has energy and environmental costs that could offset the overall benefits (FHWA, 2012).

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

Many states allow the use of fly ash and slag to replace Portland cement in concrete pavements and bridges, but often limit it to a certain percentage of replacement (Duos and Eggers, 1999). Fly ash concrete was successfully used for pavements in Texas (Estakhri and Saylak, 2005). In Missouri, a 70% slag concrete mix was successfully used in a bridge pier and abutment mass concrete project (Richardson, 2006).

Warm-mix asphalt is becoming more common in Western Europe as well as much of the U.S. WMA has been demonstrated in 43 states, and is expected to grow in popularity. In one example, WMA was used to pave a road in the Yellowstone National Park in 2007, with reported less smoke, odors, and air emissions than the traditional hot-mix asphalt (FHWA, 2011).

According to a survey conducted in 2002, 41 states in the U.S. have used recycled concrete aggregate in road construction, 38 of which used it as aggregate for base layer (FHWA, 2011). In one example, the Michigan Department of Transportation, who has used recycled concrete aggregate in road projects since 1983, found that using recycled material aggregate for an interstate reconstruction project resulted in a total savings of $130,000 (FHWA, 2004).

b. *What policy mechanism was used?*

N/A

c. *Results? Success? Uncertainties?*

N/A

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

The strategy of using alternative construction materials can be implemented by any government agency responsible for constructing and maintaining transportation infrastructure.

b. *What is the policy*

State Departments of Transportation and local governments (e.g., cities and counties) can elect to use construction materials that have lower energy requirements in their processing or application, are recycled, and/or have longer lives. Elected officials may pass legislation requiring recycled and environmentally friendlier materials in road and bridge construction and maintenance.

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

This strategy requires transportation agencies to use different construction materials from what they traditionally use. This may necessitate a change in agency culture or the adoption of new policies to ensure the use of alternative construction materials (FHWA, 2012). However, with the abundance of transportation agencies in the U.S. having already used or using alternative construction materials, the political acceptance of this strategy is already high.

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

Using alternative construction materials also provides other benefits such as less landfill for fly ash and slag, less smoke and odors from warm-mix asphalt, etc. Thus, it is likely to be publicly acceptable.

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

Alternative construction materials may also have a role in climate change adaptation, given that fly ash (FHWA, 2003), slag (SCA, 2013), and warm-mix asphalt (D'Angelo, 2008) can be more adaptable to weather extremes.

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Road Surface Improvements

I) ***Brief Summary of the Strategy including history if appropriate to provide context***

Road roughness results naturally from the gradual deterioration of road surfaces and/or the pavement structure. Not only do rougher roads reduce ride quality, they also reduce driver safety, increase vehicle wear and tear, and increase fuel consumption, which in turn increases greenhouse gas (GHG) emissions (AASHTO, 2009). Road resurfacing has been suggested as a way to improve fuel consumption and reduce GHG emissions. Yet, it is unclear whether resurfacing roads actually reduces GHG emissions due to the energy-intensive process of resurfacing roads (Lepert and Brillet, 2009).

Road resurface improvements can vary from less intensive preventative maintenance to more intensive reconstruction. They are generally part of transportation agencies' maintenance and rehabilitation programs.

II) ***Studies/Research***

a. Quantitative range of GHG reductions or fuel savings

Several studies have examined the effect of road roughness on vehicle fuel consumption. These studies found that rougher roads increase vehicle fuel consumption, and thus carbon dioxide (CO_2) emissions, between 1% and 10%, depending on the type of vehicle (e.g., cars, trucks) and the roughness of the roads considered.

- Studies have shown that reducing highway surface roughness through improved maintenance and using less flexible pavement surfaces, such as concrete rather than asphalt, can reduce fuel consumption by as much as 10% for heavy trucks, and by a smaller amount for lighter vehicles (BTCE, 1996).

- In a Missouri study of vehicle fuel economy before and after paving, diesel dump trucks were found to increase their fuel economy from an average of 5.97 miles per gallon before repaving to 6.11 miles per gallon, or about 2.4% improvement. A gasoline powered SUV was found to increase its fuel economy by about 0.8% (MDOT, 2006).

- A recent study showed that using stiffer pavements on the U.S. roads could reduce vehicle fuel consumption by as much as 3%. This would result in an annual decrease in CO_2 emissions of 46.5 million metric tons (Portland Cement Association, 2013).

- Two French studies found similar effects of road texture on vehicle fuel consumption. In one study, fuel consumption of the test passenger cars increased up to 7% when driven over rough roads as compared to when driven on smooth roads (Du Plessis et al., 1990). In the other study, fuel consumption of the test medium sized cars increased about 6% when driven on roads with poor evenness and exceptionally coarse texture (Laganier and Lucas, 1990).

b. Qualitative discussion about GHG reductions or fuel savings

The overall effect of road surface improvements on fuel consumption and CO_2 emissions also depends on many other factors. Reduction in vehicle fuel consumption is only part of the overall effect. There are CO_2 emissions generated during road resurfacing such as from construction equipment, from travel delay due to road closure, etc. After the resurfacing, there could potentially be induced travel demand (due to better driving conditions) and increased travel speed, which could increase vehicle fuel consumption and CO_2 emissions. Studies on the benefits of resurfacing rarely account for these effects (FHWA, 2012).

c. Elasticities (if available)

N/A

j. Analytical tools for analysis (if available)

Most studies define roughness based on the International Roughness Index (IRI). It is an international standard developed by the World Bank used to measure pavement roughness. It is based on a scale from zero for a true planar surface, increasing to about six meters per kilometer (m/km) for moderately rough paved roads, to 12 (m/km) for extremely rough paved roads with potholes and patches, and up to about 20 (m/km) for extremely rough unpaved roads.

k. Uncertainties/qualifications to the data

The effects of road roughness on vehicle fuel consumption vary by the type of vehicles, the speed at which they travel, etc.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

While road resurfacing occurs throughout the world, road resurfacing efforts specifically to reduce fuel consumption and CO_2 emissions have not been widely implemented.

b. What policy mechanism was used?

N/A

c. Results? Success? Uncertainties?

N/A

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

The strategy of resurfacing roads has long been implemented by all government agencies responsible for constructing and maintaining roads, including state Departments of Transportation, counties, and cities. Metropolitan Planning Organizations, although not usually responsible for resurfacing roads, also could implement this strategy by planning for and allocating funds for road resurfacing projects.

b. What is the policy

Several transportation agencies include road surface improvements as part of their pavement or asset management systems. Many states already spend most of their transportation funds on road maintenance (Smart Growth, 2011).

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

Given the high costs and uncertainty about GHG benefits, road resurfacing is unlikely to be regarded as a major strategy for reducing GHG among transportation agencies. Instead, it would be more politically acceptable to consider any GHG reduction from road surface improvement projects as secondary benefits to the primary safety and mobility benefits. In this respect, agencies would benefit from measuring GHG reductions from road resurfacing projects, which allows for full GHG analysis of agency activity.

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Generally, road resurface improvement projects are well perceived by the public as they increase driver comfort and satisfaction.

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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APPENDIX D

GOODS MOVEMENT

LITERATURE REVIEW

Double Stack Rail Network

I) *Brief Summary of the Strategy including history if appropriate to provide context*

First utilized in the early 1980s, double-stacked shipping containers allow trains to move twice as much load without needing to increase vehicle length, increasing the efficiency of freight movement. However, clearance and infrastructure projects need to be implemented in order for double-stacked trains to bypass weight and overhead obstacles, such as bridges and tunnels. (Carter, n.d.). Tracks generally do not need to be upgraded because single stacked cars, and generally double-stacked cars, rarely reach the track weight limit.

By the end of the 1980s, many railroads were successfully implementing projects to accommodate this new method of freight transport, and many major ports in the country were able to use double-stacked containers to move overseas goods to inland destinations during that time (Carter, n.d.). In 1993, 48% of container ports had adequate bridge and tunnel clearances for double-stack trains while 36% did not (Transportation Research Board, 1993). Currently, the use of double-stack rail continues to increase, with nearly 70% of U.S. intermodal shipments relying on this method and more than one million containers transported per year (Proficient Transport, Inc., n.d.). While the double-stack rail network is limited to routes that have adequate overhead clearance, they are also connected to intermodal facilities that are capable of transferring these containers to trucks for highway transport (Maryland Department of Transportation, n.d.). Efforts by federal and local governments, as well as various private entities, to expand the double-stack rail network have been met with varying degrees of success. While federal funding has been available for transportation projects that can help boost the economy (including double-stacked rail), the amount of funding allocated is often not enough to cover multiple projects. The most successful programs have been ones that can secure additional funding and support from state and local governments, private companies, and environmental groups.

According to the international transportation company CSX Transportation, along the east coast and in Midwestern states there are three maximum heights for double-stacked rail depending on the rail line used. Most networks allow for a maximum of 20 feet and 2 inches. A handful of networks allow for a maximum of 19 feet and 2 inches, and a number of networks in the Virginia-North-Carolina-Kentucky region allow for a maximum of 18 feet and 2 inches. (CSX Transportation, 2012). In Southern California, two major freight railroads, Burlington Northern Santa Fe (BNSF) and Union Pacific (UP), utilize three types of intermodal double-stacked freight trains: marine container trains that haul 20-, 40-, and 45-foot length containers, domestic container trains that haul containers in mostly 53-foot trains, and Z trains that perform expedited deliveries with double-stacked domestic containers and non-stacked trailers. In terms of environmental benefit, many of the studies and strategies discussed in this literature review have found that double-stack rail significantly decreases GHG emissions and fuel consumption in comparison to other modes of rail and road transport.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

According to the Federal Railroad Administration (FRA), double-stack rail is five times more efficient than a motor carrier moving the same load. To elaborate on how these savings occur, the FRA provides several scenarios that compare different trip lengths and load sizes. In one example, a 294-mile trip on double-stack trains with a payload of 665 tons consumes 506 gallons of rail fuel. In contrast, if trucks that can hold 11 tons of load are used, it will take 59 trucks to carry the equivalent amount, resulting in 3,113 gallons of fuel consumed (53 gallons per truck). In this scenario 2,604 gallons of fuel is saved. Longer trips have more significant fuel savings; a 2,150-mile trip on double-stack trains that carries a payload of 3,468 tons consumes 18,212 gallons of rail fuel. If trucks with a capacity of 17 tons are used, it will take 209 trucks to carry the same amount, resulting in 78,799 gallons of fuel consumed (377 gallons per truck). The amount of fuel saved due to mode shift from truck to rail from this trip is 60,587 gallons. Over a period of nearly two decades, the fuel efficiency for double-stack trains has increased, from saving between 243-350 ton-miles/gallons in 1991 to saving between 226-512 ton-miles/gallons in 2010 (Federal Highway Administration, 2009).

Forkenbrock (1998) compared the CO_2 emission rates of double-stack rail with other forms of rail and truck transport, and found that double-stack rail has the lowest emission rate per ton-mile at 15.4 grams. Intermodal rail emits 17 grams per ton-mile, mixed freight rail emits 18.6 grams per ton-mile, and heavy truck emits the most CO_2 at 135.3 grams per ton-mile.

Downsizing double-stack cars can further promote GHG reductions and fuel savings by allowing more cars to be linked per train, resulting in greater amounts of freight movement for less fuel. According to Amsted Rail (n.d.), a reduction in car length from 48 feet to 40 feet accommodates room for 4 more railcars, increasing load capacity by 16.7%. In a year, a length reduction from 48’ to 40’ saves 14,967,177 gallons of fuel by reducing fuel usage from 181,939,074 gallons to 166,870,897 gallons. A change in length also leads to a CO_2 reduction of .168 million tons annually, lowering emissions from 2,036,585 tons to 1,868,954 tons (Amsted Rail, n.d.)

b. Qualitative discussion about GHG reductions or fuel savings

According to the FRA (2009), double-stack trains display poorer aerodynamic performance and travel at higher average speeds to offset aerodynamic resistance, yet remain more fuel efficient than other types of trains. Double-stack trains also display wider variations in fuel efficiency. However, the upper range of fuel savings in double-stack trains is significantly higher than the upper range of fuel savings for all other types of trains.

c. Elasticities (if available)

N/A

d. Analytical tools for analysis (if available)

N/A

e. Uncertainties/qualifications to the data

N/A

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

National Gateway is a project that increases usage of double-stack trains in order to improve rail traffic flow between Mid-Atlantic ports and Midwestern markets. Using the information provided by the Federal Railroad Administration's 2009 report, National Gateway can achieve a 2 billion gallon fuel reduction and a 20 million ton CO_2 reduction by converting 14 billion highway miles to double-stacked rail cars (National Gateway, 2009). The project will require over $840 million in order to fund infrastructure projects that increase freight rail use. National Gateway is receiving financial support from numerous private and government entities. In 2009, National Gateway received $393 million from the transportation company CSX Corporation and its affiliates, as well as over $150 million in commitments from state governments (Ohio, Pennsylvania, Maryland, Virginia, and North Carolina) participating in the project. The project also requested $259 million in funding from Congress. Although current literature does not indicate if this specific request was granted, National Gateway received $98 million in federal funds in 2010 from the Transportation Investment Generating Economic Recovery (TIGER) Discretionary Grant program, which is part of the American Recovery and Reinvestment Act. In addition to financial assistance, National Gateway has received support from at least three dozen Congress members, three port authorities, and numerous business organizations, shippers, carriers, and environmental groups.

The Heartland Connector is a similar project that has increased the use of double-stack intermodal trains, reduced travel times, and increased service reliability from the Port of Virginia to Cincinnati and Detroit. The project consists of a public-private partnership between Norfolk Southern, the Ohio Department of Transportation, the Ohio Rail Development Commission, and the Ohio-Kentucky-Indiana Council of Governments. While GHG reductions and fuel savings have not been specified, the Port of Virginia acknowledges the positive environmental benefits of the Heartland Connector, and the project is currently the shortest, fastest double-stack route from the Port of Virginia to the Midwest (Port of Virginia, 2012).

In contrast to National Gateway and the Heartland Connector, the Chicago Region Environmental Transportation Efficiency Program (CREATE) has struggled to implement double-stacked rail strategies due to financial constraints. In 2003, the

Department of Transportation, local government, and rail carriers formed a partnership to jumpstart numerous projects to help traffic flow, including double-stacked rail. Although the project received a $100 million grant from the U.S. Department of Transportation's TIGER program for urgent projects as well as funds from other sources, funding remained short of the total needed and progress has been slow. (Rahim, 2010). In 2010, at least 11 projects have been completed, with others in construction, design, or environmental review phases. These projects include construction of new mainlines, installation of traffic control systems, and better signalization (Progressive Railroading, 2011). However, it is unknown if any of these projects include double-stacked rail.

b. *What policy mechanism was used?*

N/A

c. *Results? Success? Uncertainties?*

The extent of environmental benefits from double-stack rail has varied from state to state as a result of National Gateway projects, although all results have been positive thus far. Though a time frame was not specified, West Virginia reduced over 300,000 tons of CO_2, North Carolina reduced over 1 million tons of CO_2, Ohio reduced 2 million tons of CO_2, Pennsylvania reduced 2.5 million tons of CO_2, Maryland reduced over 2.5 million tons of CO_2, and Virginia reduced 3 million tons of CO_2 (National Gateway, n.d.).

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

The National Gateway, Heartland Connector, and CREATE programs demonstrate that implementation of double-stack rail strategies involves a variety of public and private interests that work together to provide the funding and resources to improve double-stack rail infrastructure. As demonstrated by the National Gateway project in particular, resources and support can be provided by federal government, state governments, local authorities, politicians, environmental organizations, and companies that facilitate efficient freight transportation including ports, roads, and rail (National Gateway, 2009). Such partnerships reveal that double-stack rail networks have been supported economically, politically, and environmentally.

b. *What is the policy*

While no literature has been found regarding federal or state policies that directly facilitate the expansion of the double-stacked rail network, federal programs and grants, as well as state and private funds, appear necessary to develop double- stacked networks (Rahim, 2010).

c. *Results of the policy*

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

N/A

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Chesapeake Bay Foundation, The Conservation Fund, and the Ohio Environmental Council represent a number of environmental groups that have endorsed programs such as National Gateway that implement double-stack rail projects. Further public support for double-stack rail can result from increases in job growth, with more than 50,000 jobs projected to be created over a 30 year period, and 10,000 jobs created during the initial construction phase of double-stack rail projects. National Gateway notes that half of these jobs will be located in economically disadvantaged areas hit by the recession (National Gateway, 2009).

b. Public issues concerns regarding the strategy

Double-stack rail strategies may result in financial concerns since bridges, tunnels, and other rail infrastructure must be modified to accommodate this method of freight transport. Structures that display sub-standard vertical clearances must have modifications done to the portal bracing, sway bracing, and lateral struts between trusses before becoming fit for double-stacked transport. The level of concern for this strategy likely varies by state; states such as Oregon do not have to pay for modifications since their bridges display adequate vertical clearance (David Evans and Associates, 2009).

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Intermodal Facilities Close to Ports

I) *__Brief Summary of the Strategy including history if appropriate to provide context__*

Due to their proximity to ports, intermodal container transfer facilities (ICTF) are locations that allow containers to be transferred between different modes, including ship, truck, and rail (Federal Highway Administration, 2012). According to the Union Pacific Railroad (2007), ICTFs play a key role in the interstate freight movement system by facilitating the distribution of cargo on both the regional and national level. While ICTFs have contributed to the growth of ports and intermodal freight movement, their current capacity can no longer handle the rapid increase in freight transport. A combination of federal, state, and local efforts have helped facilitate major projects to modernize ICTFs in order to increase capacity and reduce any adverse environmental effects associated with these facilities. ICTFs are made up of different components that all have related greenhouse gas (GHG) impacts, including locomotives, drayage trucks (which deliver containers between the port and the ICTF), cargo handling equipment, and reefer cars (which transport perishable and frozen goods). Thus, the ICTF strategies addressed in this literature review will look at the GHG impacts of these parts individually, as well as these facilities as a whole.

II) *__Studies/Research__*

a. *Quantitative range of GHG reductions or fuel savings*

The Alabama State Port Authority (2010) discusses the potential GHG reductions that can be generated by an ICTF project by looking at the intermodalism between ship, rail, and truck. Because ICTFs facilitate a more direct link between ship and rail, truck use can be reduced significantly. They refer to the Environmental Protection Agency, which estimates that every ton-mile of freight moved by rail instead of road reduces GHG emissions by two-thirds, and that a single freight train can carry the load of approximately 280 trucks. They conclude from these numbers that an ICTF project could, over a 25 year span, reduce more than 240,000 metric tons of GHG emissions.

b. *Qualitative discussion about GHG reductions or fuel savings*

N/A

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

According to Union Pacific Railroad (2007), different analytical tools are used depending on the component of the ICTF that is being assessed. Calculated emissions from drayage trucks are based on the number of truck trips, the length of each trip, and the amount of time spent idling. Calculated emissions from cargo handling equipment and non-cargo related heavy equipment are based on the number and type of equipment, equipment model year, equipment size, fuel type, and annual hours of operation. Calculated emissions from reefer cars are based on the average size of units, the average number of units in the shipping yard, and the hours of operation for each unit. Together, these individual components can then be used to assess the average emission rates for ICTFs.

e. Uncertainties/qualifications to the data

N/A

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

Union Pacific Corporation is the largest railroad in North America, operating in 23 states across the U.S. and linking major West Coast and Gulf Coast ports to cities such as Chicago, St. Louis, New Orleans, and Memphis. They have played a significant role in the progress of ICTF projects, submitting their first application in 2007 for intermodal facility modernization in the Port of Los Angeles. Prior to the project, the ICTF handled an average of 725,000 cargo containers annually that were transferred throughout the region and the rest of the United States, and the new project seeks to double the container handling capacity to 1.5 million containers. This ICTF project incurs environmental benefits and increases the economic growth of both the Ports of Los Angeles and Long Beach, and Union Pacific Railroad (2007) assessed how the ICTF project will decrease GHG emissions over a 10 year span, from 2005 to 2016.

b. What policy mechanism was used?

N/A

c. Results? Success? Uncertainties?

The resulting GHG emissions from ICTF modernization are determined by the different parts that make up the intermodal facility. Overall, the project is expected to emit 39,866 metric tons of CO_2 in 2016, which is 4,562 fewer metric tons per year than GHG estimates in 2005 and 4,664 fewer metric tons per year than GHG estimates in 2010. Breaking down these estimates into individual components, locomotives, drayage trucks, and reefer cars and other refrigeration units are all estimated to increase CO_2 emissions in 2016. Cargo handling equipment, which includes cranes, yard hostlers, and forklifts, and other non-cargo-related heavy equipment are estimated to significantly reduce CO_2 emissions in 2016. Finally, for miscellaneous diesel-fueled equipment used at ICTFs, CO_2 emissions are expected to remain the same. (Union Pacific Railroad, 2007).

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

The construction and modernization of ICTFs are implemented on the local, state, and federal level, with federal TIGER grants providing a significant portion of the funding needed to complete the project. On the state or local level, entities such as port authorities and individual cities sponsor or apply for these grants while finding additional sources to cover the remainder of the funding (U.S. Department of Transportation, 2012).

b. What is the policy

N/A

c. Results of the policy

In the case of the Garrows Bend ICTF, the Alabama State Port Authority received grant funding of $12,000,000 for a project that cost $28,800,000 in total. The grant will be used to connect a container facility with the national rail system, allowing for an additional two acres of rail yard for loading/unloading containers by the water's edge. The grant will also allow for the construction of a 1,225 foot rail bridge to increase connectivity between five different rail companies. The project will ultimately increase the economic and operational capacity of the ICTF while eliminating the need for polluting short-haul trucks due to the direct transfer of goods from port-to-rail (U.S. Department of Transportation, 2012).

The South Hudson Intermodal Facility is a $125,000,000 project sponsored by the City of Bayonne, New Jersey, and it was given TIGER grant funding of $11,400,000. The grant will be used to expand the capacity of the port to accommodate larger vessels, as well as allow for the direct transfer of containers from the port terminal to the national rail network. It is anticipated that the Port Authorities of New York and New Jersey will match the funds provided by the TIGER grant. Similar to the Garrows Bend ICTF project, the South Hudson Intermodal Facility will improve the efficiency of rail and port operations while reducing the number of trucks on the congested road network (U.S. Department of Transportation, 2012).

V) Political Acceptance

a. Political acceptance/resistance to the strategy

N/A

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

According to Swaim-Staley (2011), the public plays a key role in the development and siting of new ICTF projects, and in particular, CSX Transportation has worked together with the Maryland Department of Transportation to identify the best means of implementing an ICTF that will bring economic benefits to the Baltimore region, the state of Maryland, and shippers. CSX has made the process of the ICTF transparent, ensuring that businesses and residents in communities near proposed sites are actively participating in obtaining information, offering ideas and feedback, and voicing concerns. While it is unknown if other ICTF projects engage with the public to the extent that CSX Transportation and the Maryland Department of Transportation have done, it appears that public feedback and communication will play a pivotal part in public acceptance and/or resistance to the strategy.

b. *Public issues concerns regarding the strategy*

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Low Emission Freight Corridors

I) Brief Summary of the Strategy including history if appropriate to provide context

Trucks contribute nearly 20% of GHG emissions from the transportation sector and represent 17% of transportation oil consumption, which makes trucking one of the fastest growing contributors to GHG emissions in the transportation sector (Wade, 2012). Low emission zones (LEZs) in the United Kingdom (U.K.) and zero-emission corridors in Southern California have been proposed as strategies to lower emissions from freight vehicles in urban areas without affecting the overall logistical efficiency of goods movement. LEZs in the U.K. provide urban access for vehicles that meet minimum emission standards and charge large daily fees for noncompliant vehicles 24 hours a day, 365 days a year (MDS Transmodal Limited, 2012). LEZs typically apply to heavy diesel vehicles since they contribute a large amount of air pollution compared to other vehicles, but LEZs can potentially apply to all vehicles (Ellison et al., 2007). Since the primary purpose of LEZs is to promote cleaner vehicles, the U.K. government has encouraged companies that operate non-compliant heavy diesel vehicles to fit government-approved filters onto their vehicles, convert to pure gas, reorganize their fleet, replace their vehicles completely, or pay the non-compliant vehicle fee in order to enter the LEZ (Transport London, n.d.) LEZ schemes, built upon recently tightened European legislation regarding road vehicles, vary in geographic area, enforcement times, vehicle types, vehicle emission standards, and enforcement approaches (Browne et al., 2013). In Southern California, the option for zero-emission corridors is currently being studied and proposed on major interstate freeways, such as the I-710, that connect coastal cities such as Long Beach to central Los Angeles (State of California Department of Transportation & Los Angeles County Metropolitan Transportation Authority, 2012). There are limited studies regarding the GHG reduction potential of low emission zones in Europe and zero-emission corridors in Southern California, as these strategies are focused primarily on improving air quality and reducing criteria pollutants from trucks.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

A study modeling freight transport in Rome found that implementing LEZs reduced CO_2 by 312.9 tonnes between 2008 and 2012, a change of -2%. This study focused on air pollutants such as CO, NO_x, and PM, finding reductions between 13-47% for these other pollutants (MDS Transmodal Limited, 2012). These findings, coupled with a lack of literature regarding GHG reduction and low emission roadways, further reinforce LEZs as an air quality improvement strategy to meet European standards rather than a fuel efficiency and/or GHG reduction strategy. Zero-emission corridors face a similar lack of quantitative data on GHG reductions, although findings on air pollutant emissions such as CO, HC, and NO_x have been analyzed (Lee et ak,, 2008).

b. Qualitative discussion about GHG reductions or fuel savings

LEZs have demonstrated consistent beneficial effects within major metropolitan urban areas in terms of traffic reduction, air quality improvement, health, and transport system performance. MDS Transmodal Limited (2012) indicates these reasons are the primary motive for introducing LEZs in the U.K. Furthermore, the European Commission on Access Restriction Schemes (ARS) report that 91% of LEZs were introduced for environmental reasons while another 36% cited road congestion reduction. Another 18% introduced LEZs for "other" reasons. This study did not specifically cite GHG reduction or fuel efficiency as a supporting reason for LEZ implementation. Similarly, zero-emission corridors in Southern California seek to mitigate congestion and safety issues caused by the region's population, employment, and traffic volume growth, as well as increased demand for goods and aging infrastructure (State of California Department of Transportation & Los Angeles County Metropolitan Transportation Authority, 2012).

c. Elasticities (if available)

N/A

d. Analytical tools for analysis (if available)

N/A

e. Uncertainties/qualifications to the data

N/A

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

According to Browne et al. (2013) LEZs were a response to the U.K.'s air quality, particularly in London where air quality was deemed the worst in the U.K despite improvements over the past few decades. In 2000, the Air Quality Strategy for England, Scotland, Wales, and Northern Ireland was introduced to set objectives for eight different pollutants, and various options for LEZs emerged. While prominent in the U.K., several LEZs have been implemented in other European countries. In 1993, Sweden implemented LEZs, otherwise known as environmental zones, that targeted all diesel trucks and buses over 3.5 tonnes in the city centers of Stockholm, Gothenburg, and Malmo. An additional environmental zone was introduced in the city of Lund in 1999. This new scheme restricted access for vehicles over 8 years old, although older vehicles with suitable emission reduction equipment were given exemptions to the restrictions. Permit stickers and fines for illegal vehicles were used as enforcement tools, and led to a compliance rate of 90%. The strategy received favorable reviews, including low administrative costs. The assessment of the program did not consider CO_2 or fuel reduction data, instead focusing on vehicle emissions such as NO_x and particulates.

Similar proposals in Copenhagen, Norway, Italy, and Rome did not evaluate CO_2 emissions, focusing exclusively on criteria pollutants.

LEZs have not been implemented in the United States. Rather than a LEZ or environmental zone, Los Angeles is evaluating implementation of a zero-emission corridor on the I-710 Corridor. This corridor has elevated health risks due to high diesel particulate emissions, traffic congestion, truck volumes, and accident rates. The freeway was designed when import volumes were lower in the 1950s and 1960s prior to containerization of port freight, and the current infrastructure is outdated. In addition to road quality, the Port of Long Beach and the Port of Los Angeles have projected to triple in container volume by 2035, which directly affects the quantity of movement along the I-710 Corridor. The zero-emission emission corridor, otherwise known as Alternative 6B in the *I-710 Corridor Project Executive Summary,* involves both the widening of the I-710 corridor and construction of a separate four-lane freight corridor for zero-emission vehicles that receive electric power from an overhead electric power distribution system. This strategy also proposes an automated steering, braking, and accelerating system for all trucks utilizing the corridor, which allows vehicles to safely travel in groups of 6-8 and thus increases the corridor's capacity. This proposal has not yet been implemented and is under consideration by the federal government and state agencies (State of California Department of Transportation & Los Angeles County Metropolitan Transportation Authority, 2012).

b. *What policy mechanism was used?*

N/A

c. *Results? Success? Uncertainties?*

Although the I-710 project has yet to be completely refined and implemented, there are currently small-scale demonstrations that test the effectiveness of zero-emission designs. The commercialization of these designs and subsequent feasibility of a zero-emission corridor is likely to be achieved by 2035 (Environmental Leader, 2012).

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

While low emission freight corridors have not yet been implemented on a nationwide level, Southern California's proposal for zero-emission technology and a zero-emission freight corridor has been advocated on a federal level due to its relationship to the Moving Ahead for Progress in the 21st Century (MAP-21) bill. MAP-21 contains provisions for a national freight program that seeks infrastructure and operational improvements to reduce the impacts of freight by utilizing advanced technology. On a more regional level, the South Coast Air Quality Management District (AQMD), which is the air pollution control agency for Orange County and urban parts of Los Angeles, Riverside, and San Bernardino, has worked in collaboration with the Ports of Los

Angeles and Long Beach to perform zero-emission demonstration projects for rail and trucks (South Coast Air Quality Management District [AQMD], 2011).

b. *What is the policy*

N/A

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

According to the South Coast AQMD (2011), political support and potential funding may come from agencies such as the U.S. Environmental Protection Agency, the U.S. Department of Energy, the California Air Resources Board, and the California Energy Commission. Discussions between these government agencies and manufacturers, suppliers, and testing facilities have already taken place, demonstrating growing political awareness toward zero-emission technology and zero-emission freight corridors.

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

According to Browne et al. (2013), most freight operators in the U.K. would attempt to comply with LEZ regulations if introduced, using technical approaches to ensure fleet compliance or redeploying appropriate vehicles that meet LEZ requirements. Few freight operators indicated that their company would shift to alternative routes to avoid the LEZs or switch to vehicles below 3.5 tons, which are exempt from LEZ regulations. In addition, few freight operators indicated that they would enter LEZ with non-compliant vehicles and risk a fine. Other respondents to the survey, displaying a mixture of personal and company views, agreed or strongly agreed with LEZ implementation; a small minority disagreed or strongly disagreed. Browne et al. note that some respondents stated that they personally supported LEZs, but believed that the strategy was not effective from a company perspective since it involves additional costs and service disruptions.

b. *Public issues concerns regarding the strategy*

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Mode Shift — Rail and Truck

I) *Brief Summary of the Strategy including history if appropriate to provide context*

The choice of mode when moving freight involves balancing numerous tradeoffs and factors that affect the time, cost, and reliability of transporting the goods. Economic globalization has generated greater domestic freight transport since products are transported to cities within the United States and also to ports for international travel (Corbett and Winebrake, 2007). These dynamics in the freight industry have made it increasingly apparent that mode choice will produce notable environmental impacts on both the national and international scale. While two of the more common methods of freight transportation, truck and rail, have accounted for 600 million tons of oil equivalent (Mtoe) and 27% of global transport energy use in 2006, it has been determined that most of this energy is consumed by trucks. In fact, with the exception of larger countries such as the U.S. and China, the use of rail accounts for a smaller share of freight movement than trucks (International Energy Agency, 2009).There has been a slight shift toward rail in Europe during the latter half of 1995-2008, yet the modal split between road and rail freight still remains relatively constant (Den Boer et al., 2011). Meanwhile, trucks continue to dominate freight travel in the U.S., especially for trips below 550 miles. In 2007, trucks carried 72% of all freight tonnage and accounted for 42% of all ton-miles and 70% of freight commodity value. In comparison, rail only carried 11% of all freight tonnage moved and accounted for 28% of all ton-miles and 3.5% of freight commodity value (U.S. Department of Transportation, 2013). Past and current strategies have pushed industry to increase rail usage for environmental benefits through various financial incentives, such as subsidies and lower operating costs. This literature review will focus on the impact of mode shift between truck and rail on fuel consumption and GHG reductions.

II) *Studies/Research*

a. *Quantitative range of GHG reductions or fuel savings*

Numerous studies indicate that moving freight via rail is more efficient than truck, resulting in significant GHG reductions and fuel savings. The Association of American Railroads (2011) refers to an independent study for the Federal Railroad Administration that revealed that rail was four times more fuel efficient than trucks, reducing GHG emissions by 75% if freight was shifted to rail. Furthermore, it was found that a 10% shift from truck to rail would result in a reduction of 12 million tons of GHG emissions. Den Boer et al. (2011) stated similar findings, revealing that up to 20 million tonnes of CO_2 could be reduced in 2020 by making the rail network the primary means of freight transport. A more ambitious look into the future from the same study indicates an even greater savings of 86 million tonnes of CO_2 (or 22%) in freight transport by 2050 if there was a strong modal shift toward rail. A study by Janic & Vleugel (2012) that looks at Trans-European freight transportation argues that rail freight consumes less energy and emits fewer GHGs on a weekly basis. This study found that trains consumed 1,449 nanowatt-hours/week while trucks consumed 3,186 megawatt-hours/week when the ratio of rail to road was 0.455. For GHG emissions, it was found that trains emitted 667 tons of CO_2/week while trucks emitted 1,031 tons of CO_2/week when the ratio of rail to road was 0.667. Finally, a study by Zimmer & Schmeid (2008) regarding the impact of 20 tons of cargo traveling from Berlin, Germany to Porto, Portugal revealed that trucks emitted 4 tons of CO_2 and consumed 60 GJ on energy on this trip while trains only emitted 1 ton of CO_2 and consumed 30 GJ of energy.

Reductions in GHG emissions are also possible through intermodal transport by integrating rail movement with road transport rather than relying solely on road transport. A study by Craig et al. (2013) indicates that a 15% reduction in emissions is possible by 2050 through intermodal shifts. Using a data set of more than 400,000 individual intermodal shipments from more than 35,000 origin-destination lanes supplied by J.B. Hunt Transportation (year not given), the researchers found that truck freight alone would emit 1,490,986 tonnes of CO_2 while a more intermodal approach would result in 806,819 tonnes of CO_2 -- a savings of 46%. Ultimately, any attempt to reduce usage of road transport in favor of intermodal or pure rail transport results in both short-term and long-term energy, fuel, and CO_2 reductions.

b. *Qualitative discussion about GHG reductions or fuel savings*

In general, the International Energy Agency (2009) has found that improving efficiency for both truck and rail freight is a relatively low-cost procedure. Practices such as driver training, better logistic systems, and retrofit packages all contribute to CO_2 reductions and improved fuel efficiency. However, the agency also notes that rail freight is already at a point where its CO_2 efficiency exceeds that of truck freight. Further improvements to rail freight efficiency will contribute to making rail a more appealing option environmentally.

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

In order to analyze the effects of a modal shift, Wolff et al. (2009) recommends several different analytical tools that have been utilized successfully in Europe. The Marco Polo calculator outputs modal shift volume by looking at cargo weight, cargo volume, and length of trip for both the old transport road route and the new route resulting from modal shift. There are also a select number of tools that can calculate CO_2, as well as other relevant outputs, from factors relevant to modal shift. The EcoTransIT tool uses origin and destination, cargo weight, goods type, transport type, and emissions class of vehicle in order to calculate primary energy in MJ and CO_2 in tons. The ICF (Inner City Fund) tool takes cargo weight, trip length, number of segments per mode, and diesel/gasoline share in order to output CO_2 data. Finally, the NTMCalc tool uses cargo weight, trip length, and a variety of vehicle details (fuel type, engine type, vehicle type, load factor, etc.) to determine energy in MJ and CO_2 in tons (Wolff et al., 2009). Ultimately, the recommended tool used to analyze the effects of modal shift on CO_2 and fuel consumption depends on the available inputs and the preferred outputs, as well as the scenario.

e. <u>Uncertainties/qualifications to the data</u>

Connecting GHG emissions and fuel consumption with mode choice is often difficult since environmental impact is only one small factor that influences industry choice of mode. On the supply-level, industries must consider economic factors such as the production costs and price of transportation, as well as the quality of the transportation (reliability, speed, safety, frequency, flexibility, etc.). On the demand-level, industries must also consider customer demand and how customers will respond to a modal shift or modal split (Zimmer & Schmeid, 2008). In addition, rail and road often deal with different shipment and trip types, making the modal shift from road to rail a more challenging effort than some studies indicate. For example, in 2007, there was a greater modal share of trucks for trips below 550 miles and above 2000 miles. Meanwhile, there was a greater modal share of rail for trips between 550 and 2000 miles (U.S. Department of Transportation, 2013). Also, rail has the strongest position in the market for shipping bulky goods (Den Boer et al., 2011). Unless rail and road can accommodate and serve similar types of freight transport, a modal shift from road to rail to reduce GHG emissions and fuel consumption can be a difficult transition.

III) <u>Where has the strategy been implemented (if applicable)</u>

a. <u>Summary of implementation?</u>

In Europe, Marco Polo serves as a funding program for projects that shift freight transport from road to other modes (including rail), with the intention of reducing congestion, lowering pollution, and increasing the efficiency of freight transport. It is run by the European Commission’s Directorate-General for Mobility & Transport, as well as the European Union’s Executive Agency for Competitiveness and Innovation (EACI). Since 2003, more than 500 companies have implemented modal shift projects, and new projects qualify for funding each year. Rather than giving out loans, Marco Polo incentivizes companies to undertake projects by distributing grants that cover launch and operation costs without the need for repayment. These grants are results-driven, and all projects funded by Marco Polo must show they can be commercially viable within a 2 to 5 year grant period (European Commission, n.d.).

A funding strategy was also implemented by the Japanese government in 1997. Its goal was to reduce GHG emissions by 6%, or 4.4 million tons, by 2012 in order to lower emissions to 1990 levels. This goal was, in part, achieved by assisting companies with a modal shift from truck to rail through an extensive subsidy system established in 2002 (Takahashi, 2005).

In comparison to the strategies in Europe and Japan, the U.S. lacks a large-scale funding program that directly incentivizes companies to pursue modal shift projects from truck to rail through grants or subsidies. It appears that individual companies make the decision to pursue modal shift based on the market, as well as legislation that results in certain modes of transport (such as truck) becoming more cost-effective than others. Examples of truck-to-rail freight strategies in the U.S. that also evaluate GHG and fuel impacts were not found during this literature review.

b. *What policy mechanism was used?*

With a budget of €450 million between 2007 and 2013, Marco Polo funds projects based on the amount of freight shifted from road to alternative, greener modes, a fixed rate subsidy, a maximum grant duration period, and a ceiling on the costs covered. As part of the application process, companies must show how their proposed project will make a return in profit by the time the funding period ends. Under the conditions set by Marco Polo, a minimum threshold of 60 million tonne-kilometers of freight must be shifted per year. To facilitate this transition, a fixed rate subsidy of €2 per 500 tonne-kilometer is given. For modal shift projects in particular, the duration of the subsidy lasts for three years, and a 35% ceiling is set for the share of costs necessary to implement the project (European Commission, n.d.)

Similarly, Japan's 2002 subsidy system incentivized companies to initiate projects that shifted truck freight to train or ship, improved trucking efficiency, introduced advanced vehicle technology, and were proposed jointly by more than one consignor or carrier. Each project also required a CO_2 reduction of more than 81.48 tons per year. Projects that fulfilled these requirements were selected and subsidized through an auction method that sought to maximize the impacts of the subsidy by setting an annual budget of 300 million yen (3 million dollars). In 2002, 8 out of 30 proposed projects were subsidized while in 2003, 36 out of 38 projects were subsidized by the government (Takahashi, 2005).

c. *Results? Success? Uncertainties?*

Marco Polo has experienced numerous successes in shifting freight from roads to alternative modes of transport, including rail. The project "Sirius 1", led by SA des Eaux Minerales d'Evian in France and partner organization Danone Waters Deutschland GmbH in Germany, was given a €560,000 grant to facilitate a road-to-rail shift that resulted in an estimated 341 megatonne-kilometers of goods shifted off the road (European Commission, n.d.). A similar road-to-rail project called "L.O.G.I.S.T.I.C.", led by FS Logistica s.p.a. in Italy and partner organizations Montana Gas GmbH in Germany, Primagaz Central Europe GmbH in Austria, and Trenitalia s.p.a. in Italy, was given **a** €487,374 grant that resulted in an estimated 269 megatonne-kilometers of goods shifted off the road. These two projects represent a fraction of the numerous successful projects Marco Polo was able to achieve within the last decade (European Commission, n.d.).

Under Japan's modal shift strategy, six projects achieved 88.3% of their CO_2 volume reduction goal in 2002, emitting 16.4 more tons of CO_2 than the target reduction goal of 123.7 tons. In 2003, thirteen projects achieved only 75.4% of their goal, emitting 37.6 more tons of CO_2 than the target reduction goal of 115.1 tons. The results were due to unplanned inefficient transportation and poor working relationships between the carriers and consignors involved in the projects (Takahashi, 2005). Takahashi further traced the outcomes to Japan's flawed subsidy system, stating that there were too many modal shift projects from truck to rail despite Japan's extremely limited and passenger-oriented railroad network. He also criticized the subsidy system for failing to cover short-distance projects, given that large quantities of freight were being transported within urban areas. While the Japanese government was able to achieve CO_2 reductions through subsidizing modal shift projects, ineffective policy mechanisms ultimately prevented them from reaching target goals.

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

While policies to encourage intermodal spending and integration of rail freight transport and road freight transport have been enacted federally, such as in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the U.S. government has not taken an active role in mode shift. Logistics are primarily led by industries seeking lower-cost solutions for transporting goods. Thus, there are few government initiatives that directly enable modal shifts or intermodal transport, and most decisions regarding mode choice are driven by the market (Horn & Nemoto, 2004). Federal, state, and local governments can nonetheless influence freight modal shifts indirectly.

b. *What is the policy*

According to the U.S. Department of Energy (2013), federal government can affect freight modal shifts, particularly from rail to road, through truck size and weight policies that can potentially lower truck energy use, emissions, labor costs, and other operating costs. However, the net effect of size and weight policies on energy use is unknown since improved truck energy efficiency is coupled with a potential shift from rail to truck. Federal and state governments also have control over fuel tax policies and GHG pricing, influencing modal shift from truck to rail by increasing fuel taxes that subsequently raise the price of fuel. Railroads do not have to pay state motor fuel taxes since they are sourced by bulk fuel while fuels sold at commercial pumps are levied with road taxes to pay for transportation improvements (U.S. Department of Energy, 2013). Direct-user fees implemented by state and local governments, such as tolls, can also influence modal shifts for trucks by enacting container charges or other user fees that support freight investment or reduced congestion at freight facilities (U.S. Department of Energy, 2013). Finally, federal Hours-of-Service (HOS) regulations can also affect truck modal shift, particularly toward rail, by imposing daily and weekly driving limits. Currently, truck drivers have an 11-hour daily driving limit and a 70-hour work week limit. Reducing these limits any further can potentially make trucks a less competitive option (U.S. Department of Energy, 2013).

Moving Ahead for Progress in the 21st Century Act (MAP-21) hopes to evaluate the impacts of modal shift between trucks and other modes, including rail. However, MAP-

21 doesn't anticipate addressing modal shift directly; rather, this legislation includes freight modal shift research as a response to policy regarding federal truck size and weight limits and how these truck regulations affect the overall operation of the transportation system (Federal Highway Administration, 2012).

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

In the U.K., resistance to rail shifts has emerged from policies that increase the efficiency and cost-effectiveness of trucks, such as increased truck weight limits. According to McKinnon (2005), it was generally accepted that a maximum truck weight increase from 38 tonnes to 44 tonnes would be detrimental to rail freight, preventing rail from gaining new traffic while simultaneously losing traffic to heavier road vehicles. Financially, there would also be a subsequent decrease in rail freight rates in order to match lower truck freight rates, resulting in lower profits and growth for rail freight companies. The anticipated environmental benefits of increased maximum truck weights (less fuel consumption per load, lower CO_2 emissions) would further increase the appeal of shifting to truck freight.

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

Public response to modal shifts are more prevalent in literature pertaining to passenger modal shifts (such as from auto to commuter rail) than for freight modal shifts. The impacts of freight modal shift are more economically and politically driven, which is why government and industry likely hold greater interest in programs or legislation that encourage goods movement from road to rail, or vice versa.

b. *Public issues/concerns regarding the strategy*

There are issues pertaining to how freight and passenger rail will share the rail lines, given limited infrastructure capacity. Consequently, freight railroads are often unwilling to enter shared use agreements with passenger rail operators if the result could be reductions in freight service quality, speed, and safety. Thus, as freight increasingly becomes diverted to rail, transit agencies and freight railroad companies must work together to build trust and clearly define goals (Prozzi et al., 2005).

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Overweight Load Permits

I) *Brief Summary of the Strategy including history if appropriate to provide context*

Truck weights are regulated through legislation and federal/state enforcement in order to ensure environmental, infrastructural, and public safety on interstate roads. As a result of the Surface Transportation Assistance Act of 1982, the current maximum gross weight that a truck can carry on an interstate highway is 80,000 pounds (Komor, 1995). However, under special circumstances, some trucks must exceed these restrictions and are thus granted special permits by the state in order to legally carry out operations (Bilal et al., 2010). These permits apply primarily to federal and state roads while local governments continue to maintain authority over county and town roads (Cole, 2010). Permits are sold to operators on a case-by-case basis, ranging from annual permits that allow trucks that cannot be reasonably dismantled to exceed gross weight to single-trip or short-term (30, 60, and 90 day) permits for oversized loads. Since extralegal weight restrictions vary from state to state, there are also multi-state permits that allow trucks to use a single-trip permit across a number of states (Middleton et al., 2012). A standard process for obtaining a permit involves submitting an application, which is then processed to determine the correct permit type and identify permissible routes that overweight trucks are allowed to travel on. Once the application is fully processed and approved, a permit is issued to the customer, who can then file special requests for alternative routing or accommodations if necessary (Middleton et al., 2012). This process of selling and distributing permits ultimately allows extralegal truck operators to pay for the infrastructure damage that these trucks may potentially cause on interstate roads and bridges (Bilal et al., 2010). While the purpose of this literature review is to relate overweight load permits to GHG emission and fuel consumption, it appears that there is a stronger emphasis on how overweight load permits impact economic productivity, operational efficiency, and road safety.

II) *Studies/Research*

a. *Quantitative range of GHG reductions or fuel savings*

A report by Middleton et al. (2012) explains that oversized and overweight vehicles contribute 43,000-75,000 tons of CO_2 a year, with 124.4 grams of CO_2 produced for each ton-mile that an extralegal truck travels. Thus, it can be assumed that the number of overweight load permits distributed annually plays a role in the amount of additional CO_2 generated by truck travel. However, there have been no recent studies that provide concrete data as to how the distribution of overweight load permits directly affects GHG emissions.

b. *Qualitative discussion about GHG reductions or fuel savings*

The issue of oversized and overweight load permits tends to be primarily economic since industries are forced to consider numerous truck characteristics (size, number of axles, tare weight, etc.) and routing choices that affect industry productivity. Permits are also an infrastructure concern since extralegal truck travel, despite permit fees to offset damages, negatively impact road pavement and bridge conditions (Meyberg et al., 1998). Discussions of how GHG reductions and fuel savings are affected by overweight load permits appear significantly less accessible, suggesting that overweight load permits have not been a priority in past or current climate change strategies.

c. Elasticities (if available)

N/A

d. Analytical tools for analysis (if available)

N/A

e. Uncertainties/qualifications to the data

The primary uncertainties with data regarding overweight load permits come from variations in how permits are distributed, what kinds of permits are distributed, and how much extralegal weight is deemed acceptable. While Castro (2007) only describes a handful of states in detail in his report, she reveals that permits in Texas allow trucks to exceed the 40 ton limit by only 2 tons while Western Regional permits in Nevada allow trucks to weigh to as much as 80 tons gross (Nevada Department of Transportation, n.d.). In addition, there are states that strictly grant one-time permits or refuse to grant permits to trucks that can easily split up loads into smaller trucks while other states have an entire system of single-trip, monthly, and annual permits. Permit costs and distribution, which is discussed in the following section, also range quite significantly depending on state regulations. Ultimately, any study of overweight load permits is typically limited to the state or region in which the research is conducted.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

Strategies regarding permit costs and distribution vary from state-to-state, with fees ranging from $12 to $1000 for an overweight load permit. According to an article by Castro (2007), Texas distributed a greater number of permits in order to generate large amounts of revenue (approximately $7.5 million in 2007) for infrastructure repairs, with around 39,000 permits issued annually. Meanwhile, California is more cautious, issuing around 23,000 single-trip permits annually and taking the extra precaution of truckers being granted permission to travel only on a specified route for each trip. Colorado issues even fewer permits, distributing around 21,000 permits annually. Unlike California, however, Colorado truck operators rely on an honor system where drivers themselves determine which routes to take with the expectation that they will operate on permissible roads only. As an overall trend, it is reported that there are modest annual increases (2.5-3%) in the distribution of overweight-load permits (Castro, 2007).

Single source multi-state overweight/oversize permits are a current strategy that helps resolve variations and facilitates greater efficiency in how different states distribute and regulate permits. The Western Association of State Highway and Transportation Officials (WASHTO) is a coalition of 12 states, including California, which provides regional single-trip permits for extralegal vehicles. Permits are issued to trucks at entry, destination, and pass-through states on the basis that these vehicles comply with prescribed size and weight standards and travel solely on permissible routes (West Coast Corridor Coalition, 2009).

b. *What policy mechanism was used?*

N/A

c. *Results? Success? Uncertainties?*

N/A

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

Authority to issue overweight load permits occurs on a state level. In California, the California Department of Transportation has discretionary authority over issuing permits to extralegal vehicles in accordance with Division 15 of the California Vehicle Code. The Transportation Permits Branch is additionally responsible for uniform issuance of transportation permits (California Department of Transportation, n.d.). According to Bilal et al. (2010), each state's Department of Transportation is also responsible for any changes to the fee structure of these permits, although there is no mention as to how frequently these structures must be updated. For example, the Indiana Department of Transportation utilizes several different approaches in determining appropriate structures, including expert opinions, federal formulas to determine allowable weights, development of permit "design and analysis" vehicles that test the effects of different loads, and modifications to basic fee structures and policies (Bilal et al., 2010).

b. *What is the policy*

N/A

c. *Results of the policy*

Implementation of permits by each state's Department of Transportation is geared primarily to serve local industry and economic needs in response to ever-changing patterns in the distribution of commercial vehicle movements (Bilal et al., 2010). It is unknown whether or not the Department of Transportation is aware of any GHG or fuel implications while establishing new policies or structures for overweight load permits.

V) Political Acceptance

a. Political acceptance/resistance to the strategy

N/A

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

According to Cole (2010), new rules and strategies for increasing overweight load permits are typically accepted by agricultural industries (in Ohio, for example) that believe that current standards put them at a competitive disadvantage with other states and industries. However, new permit rules aren't necessarily limited to agricultural products and may impact many different industries. Railroad associations, such as the Ohio Railroad Association, oppose new permit strategies since these strategies often provide unfair subsidies for heavy trucks while simultaneously diverting freight traffic from rail to highways (Cole, 2010). Moreover, critics of overweight load permits believe that laws pertaining to these permits tend to only benefit powerful industries in the region they operate, such as logging in the West or oil and gas in Texas (Castro, 2007).

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Port and Marine Operations

I) <u>Brief Summary of the Strategy including history if appropriate to provide context</u>

According to the International Council of Clean Transportation (2011), ships are the most energy-efficient means of moving goods, and as global trade and production continue to expand, emissions from port and marine operations are expected to grow. Emissions from maritime transport come primarily in the form of CO_2, which represents 98% of total GHG emissions from ships. In 2005, international maritime activity accounted for 543.4 MT of CO_2 from fuel combustion (Crist, 2009). The ton-kilometers and carrying capacity of the maritime shipping sector nearly tripled between 1970 and 2005, and is expected to increase at least 50% from 2004 levels by 2020. Without any changes to marine practices and/or vessel efficiency GHG emissions will increase as well. Although GHG contributions from marine transportation are small compared to other modes of transportation, growth patterns reveal that these numbers will represent a larger share of emissions in the future. However, change to marine operations will be difficult because of the interregional and transnational nature of maritime shipping, creating jurisdictional and competitive pressures among differing public and private interests (Hansen et al., 2008). This literature review will look at potential port and marine efficiency measures that have been developed through collaboration between the International Council of Clean Transportation (ICCT), the International Maritime Organization (IMO), the Society of Naval Architects and Marine Engineers (SNAME), and other key partners. Potential fuel and GHG emission reductions will be assessed from an operational, ship design, and fueling standpoint (International Council of Clean Transportation [ICTT], 2011).

II) <u>Studies/Research</u>

a. <u>Quantitative range of GHG reductions or fuel savings</u>

As a whole, the ICCT (2011) concludes that a 20-40% reduction in ship emissions can be achieved depending on the measures used, the growth in ship activity, and the cost of fuel.

According to McCollum et al. (2009), GHG emissions can be mitigated by increasing the operational efficiency of ships through measures such as speed reduction, which represents a short-term mitigation option. However, speed reduction reduces total shipping capacity, requiring more frequent trips or additional ships in order to maintain the shipping supply. Speed reductions of 10 to 50% can result in immediate GHG emission reductions of 20 to 70% for container ships if no extra ships are needed to maintain the volume shipped. Speed reductions of 10 to 50% can result in GHG emission reductions of 5 to 40% if extra ships are needed to ship the same volume of goods. Ultimately, operation efficiencies in marine transportation can reduce emissions by up to 47% in the short term, and an additional 27% by 2050. McCollum et al. also propose a range of ship design efficiencies, which can reduce emissions by up to 37% in the short term, and an additional 17% by 2050. Doubling the size of ships can increase energy efficiency by 30%, a measure that is already quite popular due to industry trends toward massive cargo ships, but is simultaneously limited by practical ship size limitations. Hull and propeller optimization can reduce CO_2 emissions by 28% for each new ship. Increasing the efficiency of existing engines through engine tuning or novel hull coatings can reduce energy consumption by up to 7%, even though 96% of commercial ships already achieve efficiencies of nearly 50% due to the usage of highly efficient low- to medium- speed diesel engines. Finally, McCollum et al. propose long-term fueling and powering efficiency measures. By switching from heavy fuel oil to marine diesel oil or liquefied natural gas, a GHG reduction between 4-15% can be achieved. By 2050, a combination of liquefied natural gas and wind power could reduce emissions by up to 40%. Other sources of fuel and power, such as biofuel and solar, are also considered possible long-term yet uncertain options for marine transportation.

Hansen et al. (2008) also look at various operational, ship, and fuel efficiency strategies that can mitigate GHG emissions. For example, ship retrofits such as hull and propeller upgrades can reduce CO_2 by approximately 1-3%, while upgraded hull designs can reduce fuel consumption and CO_2 between 5 to 20%. Efficient cargo handling and mooring is expected to reduce CO_2 between 1 and 5%. Replacing heavy fuel oil with marine diesel oil can decrease CO_2 by 36 MT, or 5%, by 2020. Wind power, combined with innovative vessel design, can decrease fuel consumption by 10 to 15%. Finally, in terms of port operations, using electricity to power docked ships can reduce port GHG emissions by 66%, a measure that has been used in the Port of Los Angeles and the Port of Long Beach. In order to effectively implement electricity at ports, international shore power standards need to be adopted and new ships need to be built with shore-side electricity capacity.

Crist (2009) further explores the impact of speed reduction on fuel consumption of marine vessels. A 10% speed reduction may reduce fuel consumption by 27%. A 20% speed reduction may reduce fuel consumption by 49%. A 30% speed reduction may reduce fuel consumption by 66%, and a 40% speed reduction may reduce fuel consumption by 78%. Finally, a 50% speed reduction may reduce fuel consumption by 87%. For vessel deign, Crist estimates a CO_2 reduction range of 5-30%. For technical retrofit and maintenance strategies, Crist estimates a CO_2 reduction range of 4-20%. Ultimately, these combined measures have been estimated to reduce CO_2 emissions by up to 43% per tonne-kilometer by 2020 and 63% per tonne-kilometer by 2050. However, Crist recognizes that these numbers represent potential and that ships are designed and operated based on numerous criteria, not just fuel savings.

b. *Qualitative discussion about GHG reductions or fuel savings*

Alongside the measures proposed in the quantitative discussion of this literature review, the ICCT (2011) also proposes additional on-ship improvements such as autopilot upgrades, flow optimization, weather routing, hull cleaning, propelling polishing, waste heat recovery, air lubrication, speed-controlled pumps and fan, high-efficiency lighting, and solar power as measures to decrease GHG emissions.

Gellings (2011) further describes the potential of port electrification as a means of reducing CO_2 from shore-side sources. Gellings identifies potential strategies, such as electric cranes and forklifts that load goods on and off ships, electric and hybrid on-road vehicles that operate within ports, electric locomotives, truck stop electrification, and supplying ships with electric power from city grids instead of diesel power. Currently available commercial electric equipment include wharf cranes, forklifts, light-duty vehicles, power grids, and refrigerated containers. Since most port equipment runs on diesel fuel, electrification provides substantial emission reductions while being operationally sound. Other port operations that reduce emissions include equipment retrofit devices, repowering equipment with cleaner engines, and equipment replacement.

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

N/A

e. Uncertainties/qualifications to the data

Hansen et al. (2008) discuss three challenges assessing the viability of strategies regarding port and marine operations. Port and marine operations are transnational, resulting in complex social, economic, and political implications depending on the country or region. In addition, many strategies are sector-specific and only address a small component of the entire system. Finally, there are difficulties with finding accurate methods for quantifying GHG emissions, resulting in a lack of data availability.

III) Where has the strategy been implemented (if applicable)

a. *Summary of implementation?*

The Port of Seattle has been able to reduce CO_2 emissions by 26% annually by supplying ships with electric power rather than relying on the ships' diesel engines to supply power, a process known as "cold ironing." Ships are plugged into the city grid, which allows the ship to turn off their diesel engines but continue performing onboard services (C40 Cities, n.d.)

b. *What policy mechanism was used?*

The Port of Seattle collaborated with the maritime community, forming a voluntary public/private partnership that included vessel companies such as Princess Cruises and Holland America Line. For a ship to be supplied with electric power, vessels need to be modified. While the costs may be high for this particular strategy, a ship that frequently stops at the Port will benefit greatly. However, for ships that only dock at ports providing electricity 2-3 times each year this strategy may not be cost ineffective (C40 Cities, n.d.).

c. Results? Success? Uncertainties?

N/A

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Port and marine operations involve a mix of local, regional, national, and international operations, management, and policies, which makes policy implementation complex and contentious. Locally controlled ports, for example, may wish to reduce emissions in the immediate port area but are constrained by limited jurisdiction and competitive pressures. National policy is constrained, as the government does not want to place American maritime fleets at a competitive disadvantage with fleets from other countries. In order to deal with these competing interests, the United Nations Framework Convention on Climate Change (UNFCCC) has attempted to agree on a methodology to assign responsibility for GHG emissions on the international level (Hansen et al., 2008).

In terms of international coordination of marine transport measures, difficulties have emerged from allocating responsibility for emissions among nations. Furthermore, the lack of available instruments to determine actual levels of emissions from maritime activity makes it difficult to shift responsibility to different nations. Finally, not all nations with maritime activity are engaged with GHG reduction targets set by frameworks such as the Kyoto Protocol (Crist, 2009).

b. What is the policy

N/A

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

Different port and marine operation strategies have gained varying levels of political acceptability. The most acceptable strategies, known as the first category in Hansen et al.'s report, are ones that improve cargo handling efficiency, reduce operating costs at ports, and generate new traffic. Improved cargo handling efficiency allows for fuel savings and slower travelling speeds, which are accepted by both vessel operators and customers. Costs for such strategies would be imposed on a small group of people, and most stakeholders would ultimately benefit. The second category consists of strategies such as weather routing systems and improved propeller and hull maintenance, are relatively low cost. Costs for implementing these systems do not come from vessel operators or their customers; rather, the costs come from the manufacturers of these systems, making these strategies still feasible to a large group of stakeholders. The third category consists of strategies that involve substantial public and private costs. Private costs can come from strategies such as the implementation of wind power or innovative ship equipment/parts, such as propellers and hubs. Public costs can come from strategies such as the investment in large-scale supply equipment by port authorities. These strategies, while high cost, can result in benefits over time. The least acceptable strategies, known as the fourth category, include those related to fuel cell technology since implementing fuel cell technologies will be unlikely before 2020 and also possess high economic costs (Hansen et al., 2008).

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

According to Gellings (2011), acceptance of port and marine operation strategies come from port operators in particular. Reducing CO_2 emissions from maritime activity can potentially lead to expanded operations and overall growth.

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Truck Size and Weight Limits

I) *Brief Summary of the Strategy including history if appropriate to provide context*

Trucks, also referred to as heavy goods vehicles, are given size and weight restrictions by law. Federal regulations are enforced by state governments as a means of protecting national infrastructure and public safety, and in turn, the Federal Highway Administration of the U.S. Department of Transportation ensures that states are in compliance with legislation (U.S. Department of Transportation, n.d.). In the United States, weight standards are set by the Surface Transportation Assistance Act of 1982 at a maximum gross weight of 80,000 pounds for interstate highway travel (Komor, 1995). Although politicians and stakeholders have pushed for truck weights to exceed federal limits to as high as 97,000-100,000 pounds over the last few years through legislation such as the Safe and Efficient Transportation Act, concerns regarding safety, environmental impacts, and infrastructural damage have resulted in a standstill for future federal weight regulations. Nonetheless, truck weight increases are still possible through state exemptions and recent pilot programs that allow heavier trucks to travel on interstate highways instead of being diverted to local roads and highways.

Truck size standards are also regulated by the federal government with state enforcement of the regulations. Similar to weight standards, these restrictions are subject to future change and have been the subject of current bills in congress such as the Safe and Efficient Transportation Act of 2013 and the Safe Highways and Infrastructure Preservation Act of 2013. Currently, California allows for a maximum height of 14 feet, a maximum width of 102 inches, and a maximum length of either 40 or 60 feet depending on the vehicle type (California Department of Transportation, n.d.). In addition to these standards, trucks are also characterized into eight classes depending on each truck's gross vehicle weight (GVW), which determines the type and fuel consumption of the truck (Campbell, 1995). Because heavy-duty trucks contribute almost one-fifth of GHG emissions in the transportation sector, efforts to improve truck efficiency have revolved around new vehicle technologies and standards to curb the amount of emissions generated (Wade, 2012). This literature review will focus on research and case studies of truck size and weight restrictions regarding GHG reduction and fuel consumption.

II) *Studies/Research*

a. *Quantitative range of GHG reductions or fuel savings*

GHG reductions and fuel savings can occur from both decreases in truck weights, as well as decreases in load weights. In 2004, the Environmental Protection Agency formed a partnership called SmartWay with freight transportation industries, and through their combined efforts to improve fuel efficiency, developed various strategies and incentives to reduce fuel consumption from freight trucks. SmartWay supports truck weight reduction as a viable strategy, finding that a 10% weight drop in trucks can reduce fuel use between 5-10%. Reducing truck weight by 3000 pounds using lightweight materials such as cast aluminum alloy ultimately saves 240 gallons of gas and 2.44 metric tons of CO_2, resulting in both positive energy and fuel savings (SmartWay, n.d.). For vehicle loads, Léonardi & Baumgartner (2004) found that larger trucks carrying over 40 tons, despite higher fuel usage, demonstrated greater average CO_2 efficiency than trucks below 40 tons, with a difference of 7 tkm/kg CO_2. Additionally, a study done by Komor (1995) argues that larger and heavier trucks use less energy per ton-km due to lower levels of non-load weight and less aerodynamic drag.

b. *Qualitative discussion about GHG reductions or fuel savings*

Komor notes that larger truck weights may cause shifts in the way the freight industry operates, as greater truck productivity may incentivize companies to rely on trucks rather than other modes of transport (such as rail); this would result in greater energy consumption (Komor, 1995). Campbell (1995) finds that smaller truck weights can imply greater emissions because smaller trucks will need to make more trips than larger trucks to transport the same load size. The net result could be higher emissions despite smaller vehicles having lower emissions rates. Thus, CO_2 emissions are influenced directly by truck weights that affect vehicle performance, and also indirectly by a company's decision to use heavier or lighter fleets to maximize productivity of transporting goods. Consequently, the often indirect connection between truck weight and CO_2 emissions makes it unclear as to how GHG emissions are impacted by policies that influence truck size and weight standards. The intention behind current legislation regarding truck size and weight standards appears to be focused on economic performance and public safety.

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

McKinnon & Piecyk (2009) describe two ways to measure the impact of truck weights on CO_2 and fuel consumption, although each method has limitations in terms of providing accurate data. The first analytical tool is survey-based, where fuel efficiency estimates are determined by administering self-reported surveys based on different sizes and weights of trucks. Because these surveys are self-administered, truck haulers tend to underestimate the amount of vehicle-kilometers traveled, which consequently leads to an underestimation of fuel efficiency (McKinnon & Piecyk, 2009). For example, the Continuing Survey of Road Goods Transport (CSRGT), the largest fuel consumption survey for road haulers in Britain, reported numbers that are lower than the mean values of other surveys reporting similar data for trucks below 7.5 tons. Meanwhile, for trucks around 38 tons, CSRGT was able to report values that were more aligned with mean values of other surveys (McKinnon & Piecyk, 2009). The difference in values across surveys thus makes survey-based data a tricky analytical tool for determining the impacts of truck weights. Another tool is vehicle test-cycle estimates, which utilizes a limited sample of vehicles that are tested and extrapolated to estimate weights and sizes of other vehicles (McKinnon & Piecyk, 2009). This data is subsequently used to monitor emission levels. The primary concern with this type of analysis is that variable speeds across different traffic conditions cannot be accurately simulated through vehicle test-cycle estimates, resulting in an analysis that only reflects the conditions of the sample chosen (McKinnon & Piecyk, 2009).

e. Uncertainties/qualifications to the data

N/A

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

McKinnon (2005) describes a case study of raising the legal weight limit of trucks in the U.K. during the 1990s and 2000s, which has served as a key precedent for other European countries' decision to raise the weight limit as well. Over the span of a decade, the UK was able to increase the maximum truck weight from 38 tons to 44 tons (85,000 pounds to 97,000 pounds) as a means of consolidating loads into fewer trucks. According to government officials, this act would theoretically yield environmental and economic benefits by reducing the amount of vehicular movement generated (McKinnon, 2005). The process of implementation began by forecasting the weight increase to 44 tons and testing the extent of reductions that this new weight limit would cause. Ultimately, the forecast was successful in making a case for raising the weight limit, demonstrating an annual volume traffic reduction of 100 million vehicle-kilometers, and consequently an annual reduction of 80,000-100,000 tons of CO_2 emissions (McKinnon, 2005).

A similar weight increase strategy was used in Maine and Vermont through a pilot program that allowed up to six-axle, 100,000 pound (120,000 pounds in Vermont) trucks to travel on interstate highways. The primary purpose of this program was to assess the impacts of heavier trucks on interstate road and bridge safety. This effort included a team of several federal and state agencies organized by the U.S. Department of Transportation. After a year-long study period, the team reported their findings to the U.S. Department of Transportation. (Federal Highway Administration, n.d.).

b. What policy mechanism was used?

N/A

c. Results? Success? Uncertainties?

The 2001 truck weight increase to 44 tons has proven to be a success in the U.K., resulting in both significant fuel and CO_2 savings. In 2001, 20.1 million litres/km of fuel and 53,800 tons of CO_2 were saved. These numbers increased in subsequent years, with 39.1 million litres/lm of fuel and 104,800 tons on CO_2 saved in 2002, and 50.6 million litres/km of fuel and 135,700 tons of CO_2 saved in 2003 (McKinnon, 2005). Ultimately, by 2003, approximately 52% of trucks became licensed to operate from 38 tons to 44 tons

(McKinnon, 2005). These environmental benefits have also compelled other European countries to increase their maximum authorized vehicle weights. In Spain, government officials raised legal weight limits from 15.6 tons in 1999 to 16.3 tons in 2008. Likewise, in the Czech Republic, weight limits were raised from 7.9 tons to 12.1 tons in 2008 (Rizet, Cruz, & Mbacke, 2012). Any potential changes in mode from rail to truck due to the higher weight limits were not discussed in the European context.

After the pilot programs in Maine and Vermont were completed, heavier trucks were no longer allowed to travel on the Interstate in these two states. This meant that heavier trucks had to be diverted back onto non-federal, secondary roads. Critics of this decision believed the pilot program resulted in economic and environmental benefits while simultaneously making secondary roads safer (Straight, 2010). Meanwhile, the federal and state agencies working on the program reported notable pavement damage and reduced bridge safety as a result of heavier trucks on interstate highways. A report by the Federal Highway Administration acknowledged that six months was not a sufficient amount of time to fully analyze the effects of heavier trucks on bridges and pavements, suggesting a year-long study (Federal Highway Administration, n.d.). By 2011, Congress added Maine and Vermont to the list of states that were permitted to have trucks over 80,000 pounds travel on interstate highways (Associated Press, 2011).

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

In the United States, enforcement of truck size and weight policies are given to both federal and state governments, with the Federal Highway Administration of the U.S. Department of Transportation playing the greatest authoritative role in certifying that states are complying with the law. It is the states' role to protect road infrastructure and keep transportation efficient by enforcing maximum federal size and weight standards on interstate highways, although they can grant exemptions for overweight and oversized trucks under certain circumstances (U.S Department of Transportation, n.d.). States additionally set and enforce their height and width standards on non-interstate roads. Standards are consequently not uniform across states, and truck operators must obtain the permits necessary to legally traverse across multiple states if carrying overweight, non-divisible loads. Associations such as the Western Association of State Highway and Transportation Officials (WASHTO) have attempted to remedy the situation by offering multi-state single trip permits that allow trucks to legally pass through multiple states as long as they comply with set standards and designated routes. California, along with 17 other states, is a member of this particular effort to facilitate a more efficient transportation system (WASHTO, 2009).

b. What is the policy

Several policies in the United States and Europe have been proposed to address the environmental issues raised by truck sizes and weights. For example, a study by Sathaye, Horvath, & Madanat (2010) proposes peak-period restrictions to incentivize freight carriers to consolidate loads into larger vehicles once maximum vehicle weight regulations are increased in order to fulfill cargo requirements and meet time constraints. However, they also suggest that such a policy can also cause freight carriers to use a larger fleet of smaller trucks in order to avoid these regulations, nulling any potential benefits (Sathaye, Horvath, & Madanat, 2010). Another possibility suggested in the U.K. is increasing vehicle dimensions rather than vehicle weights. It has been found that freight is becoming less dense, thus resulting in more volume-constrained loads than weight-constrained loads (McKinnon, 2005). This issue is especially prevalent in the U.S., where average operating weights have decreased in response to a cargo density decrease (McKinnon, 2005).

c. *Results of the policy*

N/A

V) ***Political Acceptance***

a. *Political acceptance/resistance to the strategy*

In the U.K., policies for increasing loads and weights are promoted by government due to environmental and economic benefits, as evidenced by the legal maximum weight limit increase to 44 tons (97,000 pounds) in 2001. However, similar policies are often difficult to implement in the U.S. due to variations in regulation across different scales ranging from the federal to the local level. Maximum Federal limits are set by legislation and enforced by the Federal Highway Administration, while individual states comply with the maximum or grant exemptions to exceed them under certain circumstances. In addition, federal size and weight regulations apply to interstate highways rather than smaller local roads, resulting in states diverting travel of oversized and overweight trucks to local highways and roads that they have greater control over (Associated Press, 2011). In contrast, weight limits in the U.K. apply across all roads in all parts of the country, and size and weight limits are decoupled from one another (McKinnon, 2005). Over the last few decades in the U.S., proposals for federal laws to be amended have been contentious. Efforts have been made in ISTEA (Intermodal Surface Transportation Efficiency Act) in 1991, as well as MAP-21 (Moving Ahead for Progress in the 21st Century Act), but there is nothing in these policies that indicate changes to size and weight provisions (Komor, 1995) (Federal Highway Administration, 2012).

There continues to be numerous proposed bills pertaining to increasing, freezing, or circumventing truck sizes and weights on interstate highways from both the House of Representatives and the Senate, and each bill has experienced varying levels of success, criticism, and revision by politicians. An unsuccessful bill proposed in 2011 called the Commercial Truck Safety Act, S. 1540, 112th Congress (2011) allowed for trucks to exceed the maximum legal weight limit by permitting states to petition for permanent waivers from the Secretary of Transportation. Another recent bill was the American Energy and Infrastructure Jobs Act of 2012, H.R. 7, 112th Congress (2012), which would allow truck weight limits to increase to 97,000 pounds and allow double and triple-trailer trucks; the bill died as of February 2, 2012. A currently active bill that has been referred to Committee is the Safe and Efficient Transportation Act of 2013, H.R. 612, 113th Congress (2013), which allows states to authorize a vehicle to exceed the maximum gross weight as long as it fits within certain criteria, such as the gross weight not exceeding 97,000 pounds. In contrast to bills that push for higher weight limits, the Safe Highways and Infrastructure Preservation Act, H.R. 1574, 113th Congress (2013) hopes to instead freeze size and weight limitations for vehicles, and the bill has recently been referred to Committee. Ultimately, because progress for future size and weight limits is often stuck in Congress, trucks heavier than 80,000 pounds on interstate highways must either divert travel to non-interstate roads or be granted exceptions, something that has been done in at least 20 states (Associated Press, 2011). California continues to comply with the 80,000 pound limit, although the state does grant oversize and overweight permits on the basis that trucks out of compliance contain non-reducible loads (California Department of Transportation, n.d.).

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

The U.K.'s approach of increasing vehicle weights rather than vehicle sizes is a product of public concern with truck sizes. In the U.S., there are both strong proponents and critics of increased vehicle weights, which have consequently led to a lack of bipartisan support in Congress. Critics of heavier trucks believe that heavier trucks decrease highway safety due to more difficult operation controls. Additionally, heavier trucks result in greater damage to roadway and bridge infrastructure, which becomes a cost incurred by taxpayers. Some states may be granted exceptions that allow heavier vehicles in order to be more competitive and maximize productivity (Associated Press, 2011). Conversely, proponents of heavier trucks believe that highways will become safer due to a smaller number of trucks moving the same amount of goods, reducing the economic costs, emissions produced, and miles traveled. There is also mixed opinion among truck drivers themselves. Approximately half strongly disagree or disagree that air quality, global warming, and fuel consumption are problems with the trucks they drive (Schweitzer, Bodrick, & Spivey, 2008).

b. Public issues concerns regarding the strategy

According to McKinnon (2005), public concern for the increase in truck weight size comes primarily from reduced haulage costs that will consequently result in greater road freight movement generation and more freight traffic being diverted from rail to road. These public sentiments primarily reflect issues of safety and traffic caused by truck weights.

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Truck Stop Electrification

I) Brief Summary of the Strategy including history if appropriate to provide context

Federal safety regulations require that truckers must rest ten hours for every eleven hours of consecutive driving (Federal Motor Carrier Safety Administration, n.d.). As a result, drivers spend extended periods of time resting and sleeping inside the cabs of their trucks. To maintain comfort and amenities, most long haul truck drivers idle their engines for close to ten hours per day to power their heating systems and air conditioners, generate electricity for onboard appliances, charge their vehicle's batteries, and to warm their engines in colder weather (Zietsman 2009). Given that trucks typically consume 0.8 gallons of diesel fuel per hour of idling, between 900 and 1,400 gallons of fuel are consumed each year per truck, resulting in significant greenhouse gas (GHG) emissions (FHWA 2012).

Truck-stop electrification (TSE) and auxiliary power unit (APU) technologies provide long-haul truckers with the ability to heat, cool, and power additional auxiliary devices at truck stops without requiring them to idle their engines. By providing these services, it is possible to reduce or altogether eliminate excess truck engine idling, thereby reducing GHG emissions.

TSE technologies provide truckers with electricity via a standard electrical plug, or with more sophisticated off-board equipment. On board TSE solutions allow truckers the ability to recharge their batteries at truck stops via standard electrical outlets, and to utilize the truck's batteries to power appliances and provide heating and cooling. These on board TSE solutions typically require some vehicle modification. Off-board TSE solutions do not typically require any vehicle modifications, as they provide heating and air conditioning services via an overhead unit and hose that connects to the truck's window. In addition to heating and cooling, these connections also offer standard electrical outlets, internet access, movies and satellite programming (California Energy Commission, 2006 & FHWA, 2012). Both of these options can generate revenue for truck stop operators, and decrease operating / living expenses for truckers relative to the cost of diesel fuel. There are currently 115 truck stops in the United States, including ten in California, that offer TSE technology (US DOE, Alternative Fuels Data Center, n.d.).

Auxiliary power units (APUs) are another effective anti-idling technology. APUs are a mobile based technology that mounts externally to the frame of a truck to provide electricity for heating, cooling and other services via connections with the trucks cabin. An APU can be powered by a small diesel internal combustion engine that utilizes the truck's fuel supply, or it can capture electricity generated while the truck is operating and store it in batteries. Unlike TSE solutions, APUs allow truckers the freedom to enjoy heating, cooling and other amenities without restricting where the truck must stop. A survey conducted by the American Transportation Research Institute (2006) found that 36% of respondents with sleeper cabs currently used on-board idle reduction technologies. Auxiliary power units/ generators were utilized by 12% of respondents with sleeper cabs that used anti-idling technologies; this equates to nearly 5% market penetration among truckers who utilize anti idling technologies.

II) ***Studies/Research***

a. *Quantitative range of GHG reductions or fuel savings*

Utilizing TSEs or APUS to heat, cool and power auxiliary items in a truck can reduce GHG emissions by 60% or more compared to providing those amenities by idling (FHWA, 2012). The cumulative quantity of GHG emissions that can be offset depends on

b. *Elasticities (if available)*

N/A

c. *Analytical tools for analysis (if available)*

N/A

d. Uncertainties/qualifications to the data

While TSE and APU technologies seem very promising, there are some uncertainties regarding their true potential to offset GHG emissions. One particular uncertainty is in relation to the actual usage rate of TSE sites. While many TSE units can be constructed, their full utilization is not necessarily guaranteed, and their use can fluctuate over time. As a result, truck stops with TSE technologies could see varying levels of true GHG emission reductions.

Variations in fleet efficiency, local climate, carbon intensity of electricity generation, and upkeep costs of TSE can further contribute to uncertainty regarding their costs and level of GHG reductions.

In addition, because TSEs and APUs provide truckers a less expensive alternative to power their truck cabins relative to engine idling, truck drivers may utilize their appliances and other services more frequently, potentially offsetting some of the GHG reductions.

III) **Where has the strategy been implemented (if applicable)**

a. Summary of implementation?

The U.S. Department of Energy maintains a website with current TSE sites throughout the United States: http://www.afdc.energy.gov/afdc/locator/tse/. As of October 2013, the website records 115 TSE stations throughout the country. In California, there are four truck stops with TSE technologies on I-5, four on SR-99, one on I-80 and one at the intersection of SR-58 and SR-184.

The installation of both on-board and off-board TSE facilities requires a sizeable initial investment from truck stop owners and operators to construct the necessary electrical infrastructure. Similarly, on-board TSE systems can also require initial investments from truck operators to make their trucks capable of utilizing the TSE systems. To offset these initial capital costs, public agencies can provide support and incentives to promote TSE construction.

b. What policy mechanism was used?

Public agencies can encourage the adoption of TSE and APU technologies through funding and partnerships with private companies, as well as by providing financial incentives.

State DOTs, MPOs, and other agencies (state or federal) can provide funding and assist in the strategic planning necessary to help truck stop operators, as well as fleet operators, to implement on-board and off-board TSE and APUs. Such projects are frequently undertaken as public-private partnerships, and private agencies or operators may also seek funding and support from other sources (FHWA 2012).

The EPA SmartWay program is an initiative that offers guidance, financial assistance, and other resources to freight operators for using APU or TSE technologies.

c. Results? Success? Uncertainties?

TSEs can be appealing to truck stop operators as they can attract a greater volume of truckers to their location, thereby promoting further business opportunities. In addition, TSEs and APUs can reduce costs for truckers and fleet operators. Acquiring the initial funding needed to implement either strategy can sometimes be a significant hurdle.

There are some potential limitations and drawbacks to TSE facility construction and operation. In 2009, when widespread TSE construction had been going on for nearly a year, there were 138 TSE locations in operation throughout the United States. By August 2010 however, there were only 12 locations that remained in operation. This significant drop-off can be attributed to hard economic times that resulted in the primary operating company filing for bankruptcy. This suggests that TSE technology is susceptible to economic downturns (FHWA 2012). However, TSE locations have expanded again and currently there are 115 truck stops in the United States with TSE technology.

IV) ***Policy to Implement Strategy***

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

TSE and APU technologies are usually implemented by truck stop operators, truck fleet operators, and individual truck operators. However, public agencies can encourage the adoption of both TSE and APU technology by providing funding / incentives for particular organizations or by partnering with private companies. TSE projects can involve partnerships between local and state transportation agencies, other local and state organizations, federal agencies, and private companies.

In addition, states can pass anti-idling legislation that places restrictions on idling. This sort of legislation could further promote both TSE and APU technologies. According to the American Transportation Research Institute there are currently 29 states with anti-idling regulations (state and local) (2013).

b. *What is the policy*

TSE and APU projects are targeted at truck stop operators, long haul truckers, and fleet operators. By providing funding and incentives to truck stop operators, these efforts seek to first establish and enable the development of TSE facilities. Although TSE facilities allow truckers to gain amenities at lower cost compared to idling the trucks, maintaining trucker utilization of TSEs is also important. TSE and APU initiatives can also directly encourage truck fleet operators or individual truckers to install on-board vehicle equipment.

c. *Results of the policy*

According to an FHWA report (2012), public agencies have been successful in facilitating TSE projects through financial and strategic planning support. However, it is difficult to generalize given that a truck stop operator's decision to undertake a TSE project depends on numerous factors that include the total cost of implementation, the level of funding available from public sources, the demand from truckers and fleet operators, and the anticipated revenue generation.

Although public / private partnerships can facilitate the construction of TSE facilities, these collaborations can present complications and challenges.

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

There are no significant inter-agency or institutional concerns associated with APU use at this time (FHWA 2012).

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

TSE facilities are generally accepted by the public for multiple reasons. TSE facilities provide truck stop operators and technology suppliers with additional business opportunities. These facilities can attract a greater number of truck operators who wish to save money on diesel fuel, and encourage them to stay longer and purchase other items and services from the truck stop operators. Similarly, APUs are also generally accepted because they tend to save truckers and fleet operators money.

In addition, TSEs and APUs can reduce the noise and emissions that typically result from engine idling, thereby promoting an improved local air quality and environment.

Finally, TSEs and APUs can also extend the operating lifespan of diesel engines; by eliminating the need to idle, engines can be operated less frequently, diminishing the wear and tear that they might otherwise experience. This would not only improve engine performance, but could potentially diminish trucker and fleet operator expenses by increasing engine life and decreasing maintenance costs.

b. *Public issues / concerns regarding the strategy*

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

The cost of implementing a single TSE site can vary greatly, depending on the type of technology that is employed. Installation costs for technology that provides external power to operate equipment on-board a truck range from $4,500 to $8,500 per space, whereas the costs to provide a window based power unit (i.e. an off board apparatus) range from $10,000 to $20,000 per space. Costs for an individual truck operator to install an on-board system capable of utilizing shore power from a TSE space can cost up to $2,000 (EPA 2009). The Argonne National Laboratories (2000) found that the cost for on-board equipment ranges from $180 to more than $3,000.

In practice, the TSE implementation project in Pennsylvania (cited previously), found that the total cost for a single spot varied between $15,000 and $19,000 per space (Shulman 2008). Assuming a 10-year lifespan per space and no change in utilization rates, the carbon abatement cost would be between $47 and $60 per metric ton of CO_2 (FHWA 2012).

The cost of APUs, on the other hand, can range from approximately $6,000 to $7,000 depending on the specific technology that is used (Stodolsky 2000). Despite these high capital costs, it is estimated that the initial purchase price can be fully recovered by operators in 2-3 years because of lower fuel and maintenance costs (FHWA 2012).

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Urban Consolidation Centers

I) ***<u>Brief Summary of the Strategy including history if appropriate to provide context</u>***

Urban consolidation or distribution centers (UCC or UDC) are difficult to define since they are made up of a range of applications that involve both the public and private sectors. According to Browne et al. (2005), some of the terms typically associated with UCCs include *public distribution*, *urban distribution*, *central goods sorting*, *shared-user urban transshipment depot*, *cooperative delivery system*, *logistics center*, and *pick-up/drop-off location*. Browne et al. define an urban consolidation center as a logistics facility that is situated in close proximity to the area that it serves, allowing for consolidated deliveries to be carried out within that area and avoid congestion. After receiving shipments from numerous logistics companies, the UCC sorts and consolidates these loads into environmentally-friendly vehicles for delivery. Through this consolidation process, UCCs reduce the number of vehicle trips and miles, enable quicker turnarounds and loading/unloading, improve the efficiency of vehicle volume and weights, and make alternative modes and vehicles more feasible (Browne et al., 2005).

North America, Japan, Australia and most of Europe have not expanded the UCC concept any further than studies and brief experiences with it, resulting in a lack of literature in the U.S. regarding this particular topic. In contrast, the U.K. has studied and promoted multi-company UCC schemes for 25 years, although no public projects have been launched recently (Panero et al., 2011). Ultimately, UCCs result in environmental benefits, including VMT reduction, fuel savings, and CO_2 reductions, and this literature review will discuss findings and case studies that discuss UCCs' viability as a climate change strategy.

II) ***<u>Studies/Research</u>***

a. *<u>Quantitative range of GHG reductions or fuel savings</u>*

A 1996 study of UCCs in Basle, Switzerland by Browne et al. (2005) found slight reductions in both diesel and petro fuel consumption. The UCC in Basle operated as a voluntary scheme. Without UCCs, vehicles consumed 17 litres of diesel or 18.8 litres of petrol per 100 km (62 miles). With UCCs, vehicles consumed 15 litres of diesel or 18.6 litres of petrol per 100 km. In 1997, modeling estimates in Tenjin, Japan found that a total fuel consumption decrease of 0.3% is possible as a result of introducing UCCs to the area. In terms of CO_2, a study of Heathrow Airport's consolidation center found increasing CO_2 savings per year, with 1,200 kg saved in 2003 and 3,100 kg saved in 2004 (Browne et al., 2005).

A recent study of UCCs by Scott Wilson Ltd (2010) revealed that UCCs have improved both fuel and CO_2 reduction capabilities since early implementation. In comparison to Browne's studies, Scott Wilson Ltd's case studies look at four active UCCs that have similar services and operations and consist of a mix of U.K. and non-U.K. schemes identified by the South East Scotland Transport Partnership (SEStran). A UCC in Bristol saved 20.3 tons of CO_2 and resulted in 6,945 fewer vehicle trips with 178,000 fewer vehicle kilometers traveled. A London UCC achieved approximately a 75% reduction in CO_2 for deliveries from the consolidation center while reducing the number of construction vehicles traveling to delivery sites by 68%. A Monaco UCC reduced fuel and CO_2 by 26% while reducing traffic congestion by 38%. Finally, a Stockholm UCC reduced energy use and CO_2 by 90% while reducing vehicle kilometers per day from 64 km to 26 km (40 miles to 16 miles). The greater prevalence and efficiencies in UCC operations over the last decade may account for the differences between Scott Wilson Ltd's and Browne's findings.

b. *Qualitative discussion about GHG reductions or fuel savings*

UCCs help facilitate greater reduction in fossil fuel use and air pollution from goods vehicles by decreasing the total number of vehicle trips and kilometers to transport the goods. In addition, UCCs result in reductions in total traffic levels, reductions in traffic problems at delivery points, and greater use of alternatively fueled freight vehicles (Browne et al., 2005).

a. *Elasticities (if available)*

N/A

b. *Analytical tools for analysis (if available)*

Browne et al. (2005) recognizes that there are numerous ways to evaluate the effects of UCCs and there is no single analytical tool that fits all circumstances. The adoption model, utilized in the city of Belo Horizonte in Brazil, assesses both the economic and environmental impacts of UCCs. The first step of the model involves assessing the cost of adding more stages to a supply chain, the quality of delivery service, the reliability and credibility of retailers, and stock (the amount of product stored) versus exposure (the amount of product displayed). Once these inputs are established, a variety of scenarios are established in accordance with current features of urban distribution in the city. In Belo Horizonte, these scenarios look at the number of supporting UCC terminals and the rates at which these terminals are accepted and ultimately adopted by retailers utilizing the UCC. From these scenarios, fuel consumption (liters) and pollutant emissions (tons) can be assessed. For example, in one scenario where one terminal is adopted at 100% by retailers, the fuel consumption is determined to be 1.314 liters and pollutant emissions is determined to be 3.51 tons. Meanwhile, given a scenario where four supporting terminals are adopted at 60% by retailers, fuel consumption is determined to be 1.597 liters and pollutant emissions is determined to be 4.27 tons (De Assis Correia et al., 2012) The model notes decreased consumption and pollution emissions as more UCC terminals are added and adopted, with the optimal fuel consumption scenario being five UCC terminals that are adopted at 100% by retailers. However, the adoption model does indicate how much fuel or CO_2 is ultimately saved in comparison to scenarios that do not use UCCs.

Browne et al. also discuss two models that assess different UCC scenarios. The first model evaluates the effects of using better loaded vehicles to move goods from UCCs to customers in comparison to using poorly loaded vehicles that bypass the UCC and move goods directly to customers. This particular model looks at a wide range of advantages, disadvantages, and uncertainties regarding finances, traffic, freight carriers, freight receivers, and other road users, and connects these factors with the ability of UCCs to reduce fossil fuel consumption and air pollution (Browne et al., 2005). The second model evaluates the impacts of replacing direct-delivery large goods vehicles with smaller vehicles operating out of a UCC. Like the first model, this analysis looks at the connections and relationships between different players in the transportation system and concludes that UCCs ultimately result in advantageous environmental effects, such as fossil fuel reduction and decreased air pollution. However, this model is different from the previous model because it also recognizes potential for increased fossil fuel use and increased air pollution due the increased number of trips made near UCCs (Browne et al., 2005). The comparisons of these two models suggest that greater environmental impacts occur from the use of better loaded vehicles than the use of smaller vehicles.

c. Uncertainties/qualifications to the data

Many of the uncertainties with UCC evaluation come from a lack of explanation regarding research methodology. For example, it is unknown whether UCC measurements in recent studies come from actual vehicle operations or from modeling work. In addition, most studies tend to evaluate UCCs and the transportation and environmental impacts in isolation from the total amount of transportation activity in an urban area (Browne et al., 2005), which prevents further analysis of how UCCs affect CO_2 and fuel consumption in a larger context, such as on a regional or state-level.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

The U.K. and a few additional European countries have completed extensive case studies of UCCs in numerous urban areas and have found CO_2 and/or fuel savings in all examples (see Section IIa). The UCC in Bristol is a privately operated 500 square meter facility that primarily serves the retail sector. The goal is to reduce congestion and related emissions through consolidation and delivery services. For operating costs, it is funded 62% publically and 38% privately, and cost £459,000 in 2007-2008 to operate. The UCC in London is a privately operated 2,500 square meter facility that primarily serves the construction sector. It also has a goal to reduce traffic congestion and vehicle emissions through similar services as the Bristol UCC. For capital and operating costs, it is funded 58% publically and 42% privately, and the total project cost was £3.2 million. The UCC in Monaco is a privately operated 1,300 square meter facility that serves all sectors. For operating costs, it is funded 20% publically and 80% privately, and the total project cost was €412,000. Finally, the UCC in Stockholm is a privately operated 7,500 square foot facility that primarily serves the construction sector. For operating costs, it is funded 40% publically and 60% privately, and the total budget for the 5-year project was €2 million (Scott Wilson Ltd, 2010).

b. *What policy mechanism was used?*

N/A

c. *Results? Success? Uncertainties?*

N/A

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

Due to the lack of support in the U.S., there has yet to be a uniform policy approach for promoting UCC strategies. However, cities such as Portland have reviewed UCC funding initiatives by the European Commission in order to assess the feasibility of implementing a similar sustainable freight practice within the U.S. Portland determined that the Central Eastside Industrial District could be a potential UCC site because the area already serves as a platform for freight consolidation for private warehousing and distribution companies (City of Portland Bureau of Transportation, 2012). If UCC strategies in Europe are an indication of how to approach policymaking in the U.S., then implementation of UCCs will require funding and support from both federal and local governments, as well as local authorities, freight and logistics companies, and key players within the supply chain (Browne et al., 2005).

b. *What is the policy*

N/A

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

With the exception of the UCC in Tenjin, Japan, most UCC initiatives have occurred in Europe and have received strong government support, despite varying levels of acceptance by other stakeholders such as retailers and logistics companies (Panero et al., 2010). Browne et al. (2005) suggest that more can be done to raise awareness at the government-level in the U.K. For example, some local governments do not have a clear understanding of the key role UCCs can play in the development of multiple retail complexes and pedestrian-friendly streets in historic city centers and thus do not consider UCCs in policymaking. Other local governments have pushed for the central government to establish UCCs as part of major development proposals and when town centers are being restructured.

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Browne et al. (2005) indicate that low levels of support for implementing UCCs have limited the use of this strategy to reduce energy consumption and promote environmental benefits. There is a general lack of awareness of how UCCs can provide numerous economic and environmental opportunities if established correctly, and Browne et al. attributes this observation to pre-conceived assumptions that UCCs incur additional cost with little benefit. Consultants and local authorities, for example, often believe that increased cost and decreased control and security make it difficult to implement UCCs. There is a misconception that there is a single model for UCCs when in reality UCCs must be tailored and customized to fit the needs of the area that is being served. Retailers and logistics companies are also resistant to UCCs due to unclear costs and whether or not these costs can be recovered through the UCCs' ability to improve transportation efficiency. While Brown et al. recognize these concerns as valid, the authors suggest that UCCs enable opportunities to avoid congested city centers during the day and make more efficient night deliveries, reducing costs significantly. In order for a UCC to be effective, however, UCC operators must take responsibility for various "last mile" procedures and duties that logistics companies and retailers are concerned with. Finally, doubts and misconceptions regarding UCCs come from individual players in the supply chain who only consider their own part of the whole operation. Thus, it is important for future strategies to help individuals see the whole picture of how UCCs can benefit not just themselves but the entire supply chain (Browne et al., 2005)

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Weigh in Motion

I) Brief Summary of the Strategy including history if appropriate to provide context

Weigh-in-motion (WIM) systems play a pivotal role in truck weight enforcement and infrastructure safety while simultaneously increasing the efficiency of freight traffic on roads. Sensors that track the axle loads of heavy vehicles are installed beneath asphalt surfaces on the mainline or on ramps, allowing for data to be captured and analyzed without the need for these vehicles to be stopped (Mahmoudabadi & Seyedhosseini, 2012). More specifically, WIM measures and stores information about axle weight, gross vehicle weight (GVW), axle spacing, vehicle length, vehicle width, and speed. Prior to the rise of WIM technology, trucks were required to stop and queue in line at weighing stations in order to regulate vehicle loads. With these systems in place, trucks that comply with size and weight limits can continue on their routes without stopping to be checked at a nearby weighing station. This reduces the need for truckers to stop and/or slow, while allowing for enforcement of weight and size limits.

WIM systems are also often equipped with technology that electronically verifies a truck operator's credentials, further decreasing the amount of truck traffic diverted to weigh stations. Non-compliant vehicles and a random selection of compliant vehicles are directed to report to a weigh station for inspection (Government of New Brunswick, 2010). During the 1960s, the California Department of Transportation conducted research and experiments regarding WIM technology, and by 1996, the first mainline electronic weight and credential systems were installed (Regan et al., 2006). In California currently, there are at least 106 WIM collection sites in operation, and future expansion is planned (California Department of Transportation, 2009). The use of mainline WIM, in particular, is increasing throughout the United States, with approximately 550 WIM sites currently in operation nationwide that are monitored by the Federal Highway Administration for weight-based data. However, not all of these sites are used for enforcement (Federal Highway Administration, 2009). Ultimately, WIM systems decrease idling at weighing stations, which has been found to have a connection with fuel consumption and GHG emissions. This literature will look at the various WIM strategies that have been implemented in order to address the transportation, infrastructure, and environmental concerns that are associated with overloaded, non-compliant trucks.

II) Studies/Research

a. *Quantitative range of GHG reductions or fuel savings*

According to the Government of New Brunswick (2010), WIM technology addresses the issue of long term idling, which represents any form of idling longer than 15 minutes. A 2004 U.S. survey reveals that idling heavy vehicles consume 3.2 litres of fuel per hour and have a CO_2 emission factor of 2.6631 g/L. The resulting range of GHG reductions and fuel savings can be found in three case studies discussed in Section III.

b. Qualitative discussion about GHG reductions or fuel savings

Shaheen & Lipman (2007) discuss how simulation and modeling and on-road testing have shown increased fuel efficiency as a result of WIM technology. However, they also note that further research still needs to be done in order to increase the reliability of WIM since the technology used cannot be universally applied to all roads.

c. Elasticities (if available)

N/A

d. Analytical tools for analysis (if available)

N/A

e. Uncertainties/qualifications to the data

According to Nichols & Bullock (2004), size and weight enforcement is often difficult to implement due to the high level of data accuracy needed for optimal performance of WIM applications. A WIM sensor that underweighs vehicle loads may allow illegal trucks to pass through without being identified or tracked. Conversely, a WIM sensor that overweighs vehicle loads may result in legal trucks being identified as overweight. These trucks would be directed to stop at the closest weigh station for inspection, reducing enforcement efficiency while increasing fuel consumption and GHG emissions. The difficulty of calibrating sensors to accurately determine vehicle weights can consequently lead to uncertainties in studies that evaluate how WIM sensors reduce unnecessary idling at weigh stations and affect GHG emissions and fuel consumption. Depending on the calibration of WIM sensors, data collection may be influenced by overweight trucks bypassing weigh stations or compliant trucks being forced to pull over at weigh stations.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

In order to reduce GHG emissions and the number of trucks entering weigh scale stations, the New Brunswick Department of Transportation (NBDOT) purchased two WIM stations and was granted $500,000 in funding via the Climate Action Fund. Through this strategy, an emission reduction to below 25,000 tonnes of CO_2e was expected. The first station at Waewig began operations in 2008 while a second station called Salisbury East was installed near Salisbury in 2010 (Government of New Brunswick, 2010).

In Oregon, a program known as Green Light utilizes WIM scales and automated vehicle identification (AVI), which allows truck operators to pass through weight stations if they pass an instantaneous check of size, weight, height, and registration. A transponder is mounted on the windshields of registered trucks and electronic screening systems are installed at 21 weigh stations across Oregon. After passing through the WIM scales, truck drivers are notified by the transponder whether or not they can bypass the weigh station (Research and Innovative Technology Administration, n.d.). The Green Light program now serves 3,924 trucking companies and 31,104 trucks are equipped with transponders, and new WIM systems are continuing to be installed. The goals of the Green Light program, according to the Oregon Department of Transportation (n.d.), are to save time and money, lessen safety hazards caused by heavy traffic at weigh stations, and increase both driver and consumer satisfaction. Although it is unknown if GHG reductions were an initial goal for the program, substantial effort has gone into emission testing by the Oregon Department of Environmental Quality since 1999, and an emission test report was published specifically looking at Green Light programs in 2008. PrePass is similar to Oregon's Green Light program and manages 301 bypass sites in 31 states, including California. PrePass allows state and federal agencies to ensure that trucks are complying with safety and bypass criteria by equipping vehicles with a transponder that emits a signal whenever a truck passes over an electronic reader. The electronic reader provides instantaneous identification of the vehicle, and verifies if a truck's gross weight and axles are within legal limits through WIM technology. If the vehicle is compliant, the transponder emits a green light, letting truck operators know that they are allowed to bypass the weigh station. If the vehicle is non-compliant, the transponder emits a red light that signals truck operators to stop at the nearest weight station for processing. The ultimate goal of PrePass is to lower fuel and operating costs, increase productivity and time-saving, and reduce congestion around weigh stations to increase road safety (PrePass, n.d.).

b. *<u>What policy mechanism was used?</u>*

N/A

c. *<u>Results? Success? Uncertainties?</u>*

In New Brunswick, the baseline scenario for fuel consumption emissions in Waewig calculated a total of 57 litres of fuel consumed and 0.1373 kg/litres of CO_2 emitted. A similar scenario in Salisbury East revealed a total of 19,052 litres of fuel consumed and 42.8732 kg/litres of CO_2 emitted. Once the WIM stations were installed at these locations, it was found that only 1 litre of fuel was consumed and 0.0093 kg/litres of CO_2 were emitted, a reduction of approximately 93%. The study concluded before data could be collected on the Salisbury East station, but it was projected that a potential 313 litres of fuel would be consumed while 0.7120 kg/litres of CO_2 would be emitted, resulting in a reduction of over 100% (author's note: we believe they mean over 100% of their goal) (Government of New Brunswick, 2010). Ultimately, NBDOT's purchase incurred significant fuel savings and CO_2 reductions as a result of newly implemented WIM technology.

Since 2011, over 1.4 million vehicles were cleared to pass Oregon weigh stations due to Oregon's Green Light Program, resulting in a 30,576,019 pound reduction of CO_2 over the past 13 years (Oregon Department of Transportation, n.d.). Additional data provided by the Research and Innovate Technology Administration (n.d.) finds that a million bypasses from weigh stations could result in 875 metric tons of CO_2 reduced.

PrePass maintains a table of cumulative national data that reveals the extent of savings and bypasses since the technology was first implemented. As of March 2013, PrePass has allowed for 534,941,932 bypasses, resulting in 44,921,235 driving hours saved and 215,621,926 gallons of fuel saved. From California's 35 PrePass sites specifically, aggregate data reveals that the system achieved 72,138,644 bypasses, resulting in 5,924,040 driving hours saved and 28,855,457 gallons of fuel saved. Another study by the Iowa State University Center for Transportation Research and Education calculates a savings of up to 0.4 gallons of fuel with each bypass (PrePass, n.d.).

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

According to the Federal Highway Administration (n.d.), many states' WIM systems are implemented as part of the FHWA's Strategic Highway Research Program (SHRP) or Long-term Pavement Performance (LTTP) Program, which conducts pavement research by collecting data on vehicle loads. Money to deploy WIM systems has typically come from State Planning and Research (SPR) funds. Once these systems are implemented and begin collecting data, each state's Department of Transportation or Department of Highways uses the data in order to conduct further monitoring, research, and decision-making regarding pavement design.

b. What is the policy

According to the California Department of Transportation (n.d.), Caltrans WIM installation projects undergo a public bidding process. Given the limited number of WIM component manufacturers worldwide, International Road Dynamics (IRD) is the only manufacturer that bids on Caltrans installations and are thus the primary provider of WIM system components. The systems specified by Caltrans are configured to produce data regarding gross vehicle weight, individual axle weights, weigh violations, vehicle speed, overall length, axle spacing, and vehicle classification. This data is continuously gathered and stored 24/7/365 and is screened for quality before being archived or distributed to customers.

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

N/A

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

A survey was administered to truck operators by Nova Scotia Transportation and Infrastructure Renewal in 2008 to assess public opinion on fuel efficiency as a result of WIM systems. Nearly 6 in 10 respondents strongly agreed (9.1%) or agreed (50.6%) that their fuel efficiency was increased due to the new WIM system while over a quarter of respondents disagreed (24.2%) or strongly disagreed (2.2%) that fuel efficiency was increased. A greater consensus was achieved in terms of WIM accuracy and safety: 85.7% agreed that WIM was accurate in measuring truck weights while another 86.7% of respondents agreed that WIM system contributed to highway safety (Nova Scotia Transportation and Infrastructure Renewal, 2008).

b. Public issues concerns regarding the strategy

N/A

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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APPENDIX E

PUBLIC EDUCATION / BEHAVIOR

LITERATURE REVIEW

Ecodriving — Passenger

I) Brief Summary of the Strategy including history if appropriate to provide context

Eco-driving is a collection of driving behaviors that increase vehicle fuel efficiency and thus reduce greenhouse gas (GHG), especially carbon dioxide (CO_2) emissions. Eco-driving principles include, for example, accelerating and braking gently, driving at moderate speed, avoiding unnecessary idling, using cruise control where possible, and anticipating traffic to avoid coming to a full stop. In a broader sense, eco-driving also involves properly maintaining and equipping the vehicle to achieve greater vehicle fuel efficiency and lower GHG emissions. Examples include keeping appropriate level of tire pressure, removing unnecessary weight from the vehicle, using lower rolling resistance tires and lower viscosity motor oil, etc.

Eco-driving principles can be introduced to drivers in one or a combination of the following ways: 1) raising public awareness about eco-driving through education and outreach campaigns, 2) providing eco-driving classes and/or training programs, and 3) equipping vehicles with on-board devices that provide real-time eco-driving feedback information.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

Eco-driving techniques such as driving sensibly, observing speed limits, and removing excess weight have the potential to improve passenger vehicle fuel economy by 5% to 33% (U.S. Department of Energy, 2013). Eco-driving research for passenger vehicles has predominantly occurred in the European Union (E.U.) and Japan, two regions where eco-driving principles have long been promoted. North American research and programs have begun more recently. Examples are given below.

- Before-and-after driving trials in Sweden measured the effects of eco-driving on vehicle emissions and results showed average fuel savings of 10.9% after training (Johansson et al., 1999).

- Eco-driving trials conducted in the United Kingdom (U.K.) compared the fuel consumption of drivers before and after taking part in a two-hour eco-driving training, with results yielding average fuel savings of 8.5% after the training (Treatise, 2005).

- A Dutch study evaluated the effects of following eco-driving tips on fuel consumption and emissions. The study found that eco-driving techniques can reduce fuel consumption by 7 to 10%, depending on whether the vehicle is diesel or gasoline engine (Vermeulen, R. J., 2006).

- A series of eco-driving workshops were given to 225 drivers at several locations in Japan, and their fuel economy over a designed driving course was measured before and after attending the workshop. It was found that the fuel economy improved by an average of 26% after the workshops (Shinpo, 2007).

- A pilot project in Denver, CO, tracked the vehicle fuel economy of 400 participating drivers after receiving eco-driving training through the use of on-board telemetry devices. It showed that a fuel economy improvement of 10% was achieved (Enviance, 2009).

- A pilot study in Southern California evaluated the impact of an on-board eco-driving feedback device on 20 drivers over a two-week period and found an average fuel economy improvement of 6% on city roads and 1% on highways (Boriboonsomsin et al., 2011). A similar study in Northern California on 18 drivers over a four-week period found an overall fuel economy improvement of 1.4% (Martin et al., 2013). Larger-scaled eco-driving impact evaluations in the U.S. are being conducted (Stillwater and Kurani, 2012).

In addition to short-term effects, some studies also evaluated long-term benefits of eco-driving. The evaluation results of various eco-driving training programs in Europe revealed that within one year of training, drivers reduced fuel consumption by 15 to 25%. After one year, fuel savings became less significant, ranging from 4.7 to 8% (CIECA, 2007). These findings suggest the potential need for refresher courses or feedback mechanisms to prevent drivers from reverting back to old driving habits over time.

b. *Qualitative discussion about GHG reductions or fuel savings*

In contrast to eco-driving training, there are very limited data on the effects of eco-driving education campaigns as they are more difficult to measure. For the aggressive national eco-driving campaign in Netherlands, with a total population of approximately 16.4 million people, 10 million licensed drivers, and 87 million vehicle miles traveled annually, it was estimated that the campaign saved approximately 0.2 million metric tons of CO_2 emissions from passenger cars annually (Het Nieuwe Rijden, 2007).

c. *Elasticities (if available)*

It has been argued that eco-driving may be among the most cost-effective strategies to reduce GHG emissions from transportation sources (Onoda, 2009; Barkenbus, 2010). In the Netherlands, the national Dutch eco-driving campaign reported a cost of $14 per metric ton of CO_2 reduction (Het Nieuwe Rijden, 2007).

l. *Analytical tools for analysis (if available)*

Most eco-driving studies are based on real-world measurement of fuel consumption. There are several fuel consumption measurement techniques, with varying levels of sophistication and accuracy. A simple technique may just involve recording the amount of fuel dispensed (and odometer reading) at the time of refueling. Then, two consecutive records can be used to calculate the fuel consumed and fuel economy between the refills. A more sophisticated method may involve draining fuel from the tank and/or the vehicle fuel system into a container and measuring it. Furthermore, passenger cars of 1996 model year or newer are equipped with on-board diagnostics (OBD) II, which can provide estimates of fuel consumption from the engine (Boriboonsomsin et al., 2011).

After the amount of fuel consumption has been determined, the associated CO_2 emissions can be estimated based on the carbon content in the fuel. For example, there would be 19.6 and 22.4 lbs of CO_2 emissions from a gallon of gasoline and diesel fuel, respectively (Federal Register, 2010).

m. Uncertainties/qualifications to the data

There are a number of factors that can affect vehicle fuel consumption (Boriboonsomsin et al, 2011):

- *Roadway type*: City driving involves more stops (due to traffic lights, pedestrians, etc.) and is usually at a lower speed than highway driving. For cars with internal combustion engine, the former results in higher fuel consumption.

- *Vehicle weight*: A vehicle carrying more weight requires more energy to run, thus directly increasing its fuel consumption.

- *Road grade*: Climbing a steep road grade requires higher power from the engine to overcome the added gravitational force, which increases vehicle fuel consumption.

- *Weather conditions*: Weather conditions affect vehicle fuel consumption, both directly and indirectly. For instance, hot weather induces the use of air conditioning, which places accessory load requirement on the engine, and thus increases fuel consumption.

- *Congestion level*: Stop-and-go movement in congested traffic wastes fuel. Vehicle fuel consumption increases significantly under this traffic condition.

In eco-driving studies under real-world driving conditions, it may not be possible to control for all these factors during the driving periods with and without eco-driving (e.g., before and after receiving eco-driving training). Thus, the results may contain some biases due to differences in one or more of the factors discussed above, especially if the sample size is small.

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

Many countries have launched eco-driving programs to educate and train existing and new drivers to drive more economically and efficiently as a means to reduce GHG emissions and meet emission reduction targets. The vast majority of the recent and existing programs are located in European countries, including Austria, Belgium, Czech Republic, Finland, France, Greece, Italy, Latvia, Netherlands, Poland, Sweden, Spain, Slovenia, and U.K. In the Asia-Pacific region, there have been eco-driving programs in Japan, China, and Australia (Shaheen et al., 2012).

In the U.S. in September 2008, the Alliance of Automobile Manufacturers launched EcoDrivingUSA, a nationwide effort to increase fuel savings while reducing fuel consumption and emissions. Additionally, May 2009 was declared "National EcoDriving Month" to highlight the campaign and to encourage millions of U.S. drivers to practice driving more economically (Newton, 2010).

b. *What policy mechanism was used?*

The methods used in eco-driving programs vary among countries. Generally, all programs include training, outreach, and/or education components.

In terms of on-board devices, several eco-driving feedback systems have been developed by vehicle manufacturers and made available initially in their hybrid-electric vehicle models such as Toyota Prius and Ford Fusion Hybrid. In addition to these systems that come equipped with the vehicles, there have been aftermarket eco-driving feedback devices in the consumer market, in the form of personal navigation devices or smartphone apps.

c. *Results? Success? Uncertainties?*

Several European eco-driving programs have been launched since 2005. One of the more extensive programs is the ECODRIVEN project, which operated from January 2006 to December 2008 in nine countries in the E.U. The program was based on a "bottom-up" approach, relying on participating countries to promote eco-driving to their citizens in a country- and culture-specific manner. The program reached more than 20 million licensed drivers in the participating countries and resulted in 1 million metric tons of CO_2 emission avoidance between 2006 and 2010 (Intelligent Energy Europe, 2009).

IV) Policy to Implement Strategy

a. *In the United States, who would implement the policy (Fed, State, Local, agency, other?)*

Eco-driving policies for passenger vehicles may be implemented by federal, state, regional, or local agencies. Partnerships with automobile associations and public-interest organizations may be important for the success of any eco-driving policies.

b. *What is the policy*

There are several eco-driving policies for passenger vehicles that can be implemented. For instance, federal agencies may promote eco-driving as public awareness campaigns. At the state level, motor vehicle agencies may require eco-driving education and training as part of driver license exams. Other agencies and public-interest organizations may offer eco-driving education and training independently. Incentives may be provided to auto manufacturers to equip their vehicles with eco-driving supporting technologies. Incentives may also be provided to drivers for the purchase of vehicles with eco-driving feedback systems or aftermarket eco-driving feedback devices.

c. *Results of the policy*

N/A

V) Political Acceptance

a. *Political acceptance/resistance to the strategy*

There are no specific political concerns associated with eco-driving education and training programs. In fact, EcoDrivingUSA had received the support of the governors of many states and territories including Alabama, California, Colorado, Georgia, Idaho, Kentucky, Maryland, Michigan, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Utah, Virginia, West Virginia, Puerto Rico, and the U.S. Virgin Islands (Newton, 2010).

VI) Public awareness/education

a. *Public acceptance/resistance to the strategy*

The social acceptability of such programs is likely to be high given that they are voluntary. Expenditures by individuals, government, and industry for eco-driving education and training will likely be negligible at a national level. As eco-driving technology is largely undeveloped, the costs to individuals, government, and industry for such technology is unknown but conceivably would be implemented as part of ongoing vehicle technology advancements (FHWA, 2012).

Public acceptance of eco-driving policies is tied to the price of fuels. More drivers are likely to eco-drive when the fuel prices are high in order to reduce travel costs. A pilot study in Southern California evaluating the impact of an on-board eco-driving feedback device found that 19 out of the 20 participants would adopt eco-driving techniques if the gasoline price increased above $4 per gallon (Boriboonsomsin et al., 2011).

b. *Public issues concerns regarding the strategy*

There are no significant barriers to implementing eco-driving education campaigns, training programs, and technology supports given that eco-driving is voluntary and these policies can be low-cost. However, persuading the general public to eco-drive and therefore to achieve the outcomes of these policies may be more difficult (FHWA, 2012).

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Ecodriving — Freight

I) ***Brief Summary of the Strategy including history if appropriate to provide context***

With volatile gas prices and increasing concerns about climate change, freight companies and independent owner/operators are looking for simple, low-cost methods to increase fuel economy, reduce spending on fuel, and decrease carbon emissions. One method that some companies and policy makers are now turning toward is eco-driving. Eco-driving encourages a number of driving behaviors and vehicle maintenance practices that maximize fuel economy of existing vehicles while minimizing their carbon dioxide (CO_2) emissions. Eco-driving principles for freight trucks include maintaining a constant speed, using a moderate speed on the highway, accelerating smoothly, decelerating gradually using the engine brake, avoiding unnecessary idling, and keeping tires properly inflated (Isuzu Commercial Truck of America, 2010).

II) ***Studies/Research***

a. *Quantitative range of GHG reductions or fuel savings*

Most eco-driving research for freight vehicles has occurred in the European Union (E.U.) and Japan, two regions where eco-driving principles have long been promoted. North American research and programs have begun more recently. Examples are given below.

- A 2003 DHL Finland study found that the drivers of Air Express service recorded fuel savings of 17% per stop and 11% per kilometer after having received eco-driving training (DHL Finland, 2003).

- A Slovenian study evaluated the results of eco-driving training at three companies: a freight transport company, a waste management company, and a municipal utility company. A selection of drivers from all three companies was trained from November 2008 to January 2009. Following the training, the drivers were monitored for six months. Results show that fuel consumption reductions ranged from 1.4% to 7% (Bozicnik and Hanzic, 2009).

- A comparative study in Japan involving five drivers was conducted (Saito et al., 2008). The drivers drove a light-duty freight vehicle during two sessions, once without using eco-driving techniques and once with the techniques. Results showed that CO_2 emissions were reduced by about 15% when using the eco-driving techniques.

- In Australia, a study involving 12 drivers, randomly selected from three companies, showed savings of up to 27% in fuel consumption (Symmons and Rose, 2009). The drivers were split into: 1) a control group (no training), 2) a group that received classroom theory training, and 3) a group that received classroom theory and on-road training. Drivers were assessed immediately after training, at six weeks, and again at 12 weeks after completing their assigned training. Drivers that received video and on-road training reduced fuel consumption with less frequent gear changes and fewer brake applications, which continued into the 12th week.

- A Canadian trucking company initiated a project in 2004 to provide eco-driving training to truck drivers and install monitoring technology in the vehicles to identify poor driving practices. The combination of these two practices resulted in reduced idling time from 48.3% to 17%, fuel savings of 3%, and an approximate annual reduction of 1,000 metric tons of CO_2 emissions (Natural Resources Canada, 2013).

b. *Qualitative discussion about GHG reductions or fuel savings*

Experts in the freight industry agree that more than just eco-driving training is necessary to maintain efficient driving habits in the long term. One method for incentivizing eco-driving habits is reward schemes centered on bonuses for every mile per gallon (mpg) of increased fuel economy. Another method for motivating drivers to continue using eco-driving principles is the usage of on-board monitoring systems. These systems are able to record real-time information about brake usage, gear shifting, and fuel consumption and to remind drivers of eco-driving tips. As more freight companies adopt eco-driving as a means of reducing fuel costs and CO_2 emissions, other methods for ensuring long-term efficient driving behavior may need to be determined in order to maintain eco-driving benefits (Jones, 2007).

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

Most, if not all, eco-driving studies are based on real-world measurement of fuel consumption. There are several fuel consumption measurement techniques, with varying levels of sophistication and accuracy. A simple technique may just involve recording the amount of fuel dispensed (and odometer reading) at the time of refueling. Then, two consecutive records can be used to calculate the fuel consumed and fuel economy between the refills. A more sophisticated method may involve draining fuel from the tank and/or the vehicle fuel system into a container and measuring it. Furthermore, most freight vehicles on roads today are equipped with engine control unit (ECU), which can provide direct readings of fuel consumption from the engine (Boriboonsomsin et al., 2010).

After the amount of fuel consumption has been determined, the associated CO_2 emissions can be estimated based on the carbon content in the fuel. For example, there would be 19.6 and 22.4 lbs of CO_2 emissions from a gallon of gasoline and diesel fuel, respectively (Federal Register, 2010).

e. <u>Uncertainties/qualifications to the data</u>

There are a number of factors that can affect vehicle fuel consumption (Boriboonsomsin et al, 2011):

- *Roadway type*: Driving in cities involves more stops (due to traffic lights, pedestrians, etc.) and is usually at a lower speed than highway driving. For freight vehicles with internal combustion engines, the former results in higher fuel consumption.

- *Vehicle weight*: A vehicle carrying more weight requires more energy to run, thus directly increasing its fuel consumption.

- *Road grade*: Climbing a steep road grade requires higher power from the engine to overcome the added gravitational force, which increases vehicle fuel consumption.

- *Weather conditions*: Weather conditions affect vehicle fuel consumption, both directly and indirectly. For instance, headwind increases fuel consumption as the vehicle needs additional power from the engine to combat the wind drag. Hot weather induces the use of air conditioning, which places accessory load requirement on the engine, and thus increases fuel consumption.

- *Congestion level*: Stop-and-go movement in congested traffic wastes fuel. Vehicle fuel consumption increases significantly under this traffic condition.

In eco-driving studies under real-world driving conditions, it may not be possible to control for all these factors during the driving periods with and without eco-driving (e.g., before and after receiving eco-driving training). Thus, the results may contain some biases due to differences in one or more of the factors discussed above, especially if the sample size is small.

III) <u>Where has the strategy been implemented (if applicable)</u>

a. Summary of implementation?

E.U. countries have had experience with freight eco-driving training programs and campaigns since the late 1990s. The Dutch national eco-driving campaign, started in 1999 and scheduled to end in 2013, involves educating new and experienced drivers on the principles of eco-driving and has created a number of consumer and commercial partnerships to spread the message. The campaign evaluation in 2006 estimated 0.10 million metric tons of CO_2 annual reductions in freight and public transport emissions (Het Nieuwe Rijden, 2007).

FLEAT is another large E.U. project specifically targeting fleet vehicles. One of its key components is eco-driving education for drivers and driver trainers. Three truck fleets, with a total of 322 vehicles, were involved in the FLEAT pilot programs. The drivers of the trucks were given an extended eco-driving course followed by an extensive feedback regime featuring monitoring and refresher courses. The truck fleets achieved fuel reductions ranging from 8.5% to 11.4%, with an average of 9.4%. In addition, annual CO_2 emissions from the truck fleets were reduced by 1,923 metric tons (Intelligent Energy Europe, 2009).

General eco-driving practices have also been incorporated into freight vehicle licensing exams in Sweden. Since 2009, the Swedish Road Administration has included an eco-driving component in both the written test and the driving test. Officials hope that this measure will result in a 10% to 20% reduction in fuel consumption (Swedish Transport Administration, 2010).

In the Asia Pacific region, Japan is at the forefront in promoting eco-driving. For instance, a Japanese truck manufacturer, Isuzu Motors Ltd., has offered a series of Fuel Economy Challenges across Japan. Since its inception, more than 10,000 drivers and fleet managers have visited the company's proving grounds in Hokkaido to participate in the challenge. Participants drove vehicles provided by Isuzu to navigate a course which included both city and intercity driving. After the initial run, participants were instructed to reduce their highway speed, avoid aggressive starts, avoid using the exhaust brake, and reduce idling. Following the instruction, participants drove the same course again to monitor any change in fuel economy. Using the eco-driving techniques, participants realized an average fuel savings of 33% (Antich, 2009).

In 2007, Isuzu Commercial Truck of America began offering the Fuel Economy Challenge for fleet managers in the United States (U.S.). The challenge was structured in the same way as the Fuel Economy Challenge offered in Japan. Participants improved vehicle fuel economy by 33.6-40.5% (Fleet Owner, 2007).

b. What policy mechanism was used?

In addition to eco-driving education and training, there are other mechanisms that have been used to promote and sustain eco-driving habits among freight drivers. For example, in 2008 a water company in Maine began using its on-board computers, which were previously used only as electronic log books, to track the idling time of their trucks. The company then implemented a reward system for drivers who reduce idling. Within two years, idling time was reduced from 1,400 hours per month to 380 hours per month. This reduced the fleet's fuel consumption by 8,000 gallons and CO_2 emissions by about 77 tons per year (Environmental Defense Fund, 2009).

In Canada, several organizations have used a combination of eco-driving training and real-time monitoring of driver performance to improve fleet fuel efficiency. A food distribution company in British Columbia employs an incentive program that pays back its drivers half of the fleet's fuel savings. The company saw a fleet fuel efficiency improvement of 24% in the first month (Natural Resources Canada, 2013).

Also in Canada, companies in Prince George, British Columbia, have begun participating in a pilot project to reduce fuel consumption while generating carbon offsets for sale. The Carbon Offset Aggregation Cooperative (COAC) was founded in January 2011 to assist owners of trucks and heavy equipment in overcoming technological and financial barriers to making carbon reduction changes to their operating practices. Participating vehicles are equipped with on-board computers to record operations and determine baseline fuel consumption. To reduce fuel consumption, the program implements technological changes and promotes behavioral changes such as eco-driving. The COAC provides all the services, information, labor and maintenance, thus removing many of the barriers to implementing fuel-saving practices. The carbon offsets generated through the program are then sold to Pacific Carbon Trust (Carbon Offset Aggregation Cooperative, 2011).

c. Results? Success? Uncertainties?

See III.a and III.b above.

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Eco-driving policies for freight vehicles may be implemented by federal, state, regional, or local agencies. Partnerships with the freight industry may be important for the success of any eco-driving policies.

b. What is the policy

There are several eco-driving policies for freight vehicles that can be implemented. For instance, federal agencies may promote eco-driving as public awareness campaigns. At the state level, motor vehicle agencies may require eco-driving education and training as part of freight vehicle licensing exams. Regional and local agencies may impose anti-idling regulations to discourage extended idling by freight vehicles.

c. Results of the policy

N/A

V) Political Acceptance

a. Political acceptance/resistance to the strategy

In 2010, the United Kingdom (U.K)'s Department for Transport was considering a proposal to make an eco-driving training course a mandatory component of the E.U.

Driver Certificate of Professional Competence process (Aviva, 2010). After consultation with the freight industry, however, the department decided not to mandate such regulation, but instead to encourage and support industry-led initiatives to improve fuel efficiency and reduce carbon emissions from freight vehicles (Department for Transport, 2013).
Based on interviews with fleet managers, they have chosen to install equipment that promotes or enforces eco-driving, such as speed governor or trailer skirt, rather than provide eco-driving training, as the former approach does not require driver compliance and can be easily integrated into existing maintenance schedules. For many fleet managers, the chief concern is cost savings. Environmental benefits are a positive side effect, but they are not necessarily a game changer. They suggest promoting eco-driving practices as "fuel conservation" or "driver efficiency," because many of them feel overwhelmed by environmental messages and are wary of them (Shaheen et al., 2012).

VI) Public awareness/education

a. Public acceptance/resistance to the strategy

Based on interviews with regulators, educators, advocators, and managers in the freight industry in the U.S., they viewed eco-driving practices as the most effective way to reduce fuel consumption, but believed that it was most difficult to change driver behavior. Drivers can be resistant to change as they are used to driving in their preferred way. However, proper recognition and financial incentive can be a very effective way to encourage eco-driving habits (Shaheen et al., 2012).

b. Public issues concerns regarding the strategy

For fleet managers, high turnover rates in the industry lead many of them to be reluctant to invest in eco-driving training for fear of losing trained employees. For drivers, tight delivery schedules planned by dispatchers sometime cause them to prioritize speed over fuel savings (Shaheen et al., 2012).

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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Reduce Speed Limits

I) Brief Summary of the Strategy including history if appropriate to provide context

Speed limits and speed enforcement are often used as mechanisms for influencing traffic volume and accident reduction, but they have also played a role in reducing fuel consumption, which impacts GHG emissions. During World War II and later during the 1973 Middle East War, Americans were asked to reduce their driving speed in order to conserve fuel for military use. During the 1973 war in particular, President Nixon recommended that state governments voluntarily reduce the speed limit to 50 miles per hour (MPH) (Boulter, 1980). Due to concerns that this recommended speed limit was too low, the executive branch worked with state government officials and other stakeholders to set the federal maximum speed limit to 55 MPH for all vehicles. Numerous stakeholders continued to disagree with the 55 MPH speed limit for economic and personal reasons (Boulter, 1980). Federal speed limits began to increase over the next few decades as concerns for fuel conservation diminished. The right to control speed limits was given to the states in 1995 under the National Highway System Designation Act (Dutta & Noyce). While this literature review will focus particularly on speed limit and speed enforcement strategies that can reduce fuel consumption and greenhouse gas emissions, current and proposed speed limit policies have additional economic and safety dimensions to them as well.

II) Studies/Research

a. Quantitative range of GHG reductions or fuel savings

A study done in the United States by the Center for Clean Air Policy in 2004 revealed that a speed limit reduction from 65 MPH to 55 MPH would reduce CO_2 annually by 11,000 metric tons (Federal Highway Administration [FHWA], 2012). Similarly, several studies completed in Europe on two different types of roads have demonstrated notable reductions in CO_2 as a result of lowered speed limits. On open roads with greater speed limits, Archer et al. (2008) found that lowering the speed from 130 km/h to 100 km/h (81 MPH to 62 MPH) in Austria resulted in a 25% reduction of CO_2 while a related study in Netherlands resulted in a 34% reduction of CO_2 when speeds were lowered from 111 km/h to 104 km/h (69 MPH to 65 MPH). A study on residential roads by Madireddy et al. (2011) yielded comparable results, with CO_2 being reduced by 25% when speed limits in neighborhoods were lowered from 50 km/h to 30 km/h (31 MPH to 19 MPH). However, it has also been found that there is a limit to how low speeds can be reduced before emissions begin to increase. Emissions increase rapidly from 40% to 400% when speeds are lowered down from 25 km/h (16 MPH), resulting in a subsequent increase in energy consumption by a maximum of 57.5% (Mao et al., 2012). Ultimately, in terms of an ideal speed limit, Jabali et al. (2012) argue that an 85 km/h (53 MPH) speed limit results in positive environmental and economic benefits by optimally minimizing both travel times and emissions. The American Association of State Highway and Transportation Officials supports a similar optimal speed limit of between 45-55 MPH, believing that speeds beyond this range quickly increases fuel use (FHWA, 2012).

In addition to speed limit reduction, studies in the United States have demonstrated notable gasoline and CO_2 savings from speed limit enforcement. A 1996 study by the Washington State Energy Office revealed annual savings of approximate 105 million gallons of gasoline and 933,000 metric tons of CO_2 if 55 and 65 MPH speed limits were enforced (FHWA, 2012). Similarly, a study in 2003 by the New York State Greenhouse Gas Task Force revealed that full enforcement of speed limits would lead to a reduction of 0.047 MMTC in 2010 and 0.070 MMTC in 2020, from baseline 1990 emissions levels (FHWA, 2012) (Center for Clean Air Policy, 2003). Another study in the U.K. by Fergusson (1994) notes that simply enforcement alone, without changing speed limits, has the potential to reduce CO_2 by 3%, or 2.25 MT.

b. *Qualitative discussion about GHG reductions or fuel savings*

Fuel consumption and emissions are also determined by behavioral and design factors that influence driver speeds. For example, regardless of speed limits, aggressive driving can lead to sharp increases in fuel consumptions and emissions (Int Panis, Broekx, & Liu, 2006). Meanwhile, speed limits coupled with proper traffic calming measures can encourage drivers to lower their acceleration, providing fewer emissions and greater fuel efficiency (Archer et al., 2008)

c. *Elasticities (if available)*

N/A

d. *Analytical tools for analysis (if available)*

Analysis of emissions in response to various speed limits involves the integration of a variety factors including policy effects and behavioral responses that allow impacts to be evaluated in real-time. Int Panis, Broekx, & Liu (2006) utilize microscopic modeling to simulate traffic and emissions, and the combination of the two factors result in the ability to determine emissions based on driver speeds. A microscopic traffic simulation model, which can be based on any pre-existing traffic microsimulation model, provides the real-time driving conditions that help determine speed and acceleration. This allows the microscopic emission model to use the real-time data acquired from the traffic model to determine vehicle emissions rather than using more laboratory-based data (Int Panis, Broekx, & Liu, 2006). Besides microscopic modeling, Van Beek et al. (2007) also discuss modeling emissions on a mesoscopic level, which analyzes gas-kinetics and aggregate behavior of individual vehicles, and on a macroscopic level, which looks at traffic streams moving through a network during a certain time of day. Thus, there is a range of analytical tools on different scales that can relate emissions to driver speed and in turn be used to influence relevant policies.

The Federal Highway Administration (2012), in particular, suggests two specific analytical tools. The first, Motor Vehicle Emissions Simulator (MOVES), estimates how speed changes affect emissions, making it a flexible model for conducting other types of analyses, such as transportation conformity for criteria pollutants. The second, Comprehensive Modal Emissions Modal (CMEM), can work in tandem with other transportation models and data sets in order to perform an analysis on fuel consumption (FHWA, 2012).

e. Uncertainties/qualifications to the data

The primary uncertainties with speed and GHG emissions data result from a lack of enforcement of speed limits and the inability to obtain direct measurements of the relationship between driving behavior and vehicle emissions, despite behavior and emissions sharing a strong correlation (Int Panis, Broekx, & Liu, 2006). Speed reduction, for example, can result in reduced congestion and bottlenecking that reduce GHG emissions; on the other hand, speed reduction can also promote congestion and less road capacity, which result in greater GHG emissions. Considering these uncertainties, it may be possible that further improvements to GHG emissions and fuel efficiency may be attributed to factors besides speed limit reductions (FHWA, 2012).

III) Where has the strategy been implemented (if applicable)

a. Summary of implementation?

This literature review looks at three different strategies in speed limit reduction that have been implemented in Europe. The first strategy, in the city of Ghent in Belgium, involved entire residential districts and streets being converted from 50 km/h to 30 km/h (31 MPH to 19 MPH) zones. While the lowered speed limits were primarily geared toward traffic safety, this strategy was also acknowledged as being environmentally beneficial since similar speed limit strategies implemented on highways resulted in reduced fuel consumption (Int Panis, Broekx, & Beckx, 2006). A different strategy in the Netherlands, known as Drive Slow Go Faster (DGSF), took an indirect approach to speed limit reduction by promoting lower speeds through road redesign and traffic calming measures (Van Beek et al., 2007). The final strategy, also implemented in the Netherlands, introduced a system of differentiated speed limits depending on the vehicle type and road segment. In particular, speed limits for passenger vehicles were limited to 100 km/h (62 MPH) or 120 km/h (75 MPH) on particular sections of Dutch motorways (Den Tonkelaar, 1994).

b. What policy mechanism was used?

N/A

c. Results? Success? Uncertainties?

These three different strategies (speed limit reductions in entire residential districts, indirect speed limit reduction through road redesign, and differentiated speed limits) have yielded a diverse set of results. The strategy of district-wide speed limit reductions in Ghent demonstrated that emissions for CO_2 and fuel consumption had a limited impact, proving that strategies that are successful on highways do not necessarily result in similar impacts when implemented in a different setting (Int Panis, Broekx, & Beckx 2006). The Netherlands' DGSF strategy was more successful, and the road redesigns resulted in a 26% energy reduction (Van Beek et al., 2007). The differentiated speed limit strategy had both positives and negatives associated with it: while there was a temporary decrease in emissions and fuel consumption for the first year that these speed limits were in place, a lack of enforcement resulted in increases in driving speeds during the second and third years of implementation (Den Tonkelaar, 1994).

IV) Policy to Implement Strategy

a. In the United States, who would implement the policy (Fed, State, Local, agency, other?)

Due to state control of speed limits, the California Department of Transportation has authority in implementing any changes to the speed limit, and these powers are given to them by Sections 21400 and 21401 of the California Vehicle Code (California Department of Transportation, 2009). The most recent guideline for implementing speed limits was established when local agencies and officials from law enforcement, public works, and the court system came together in 2007 to discuss speed limit concerns. In 2009, the Director of the Department of Transportation and the California Highway Patrol Commissioner conducted a special hearing that ultimately resulted in the issuance of the current document that directs speed limit policies (California Department of Transportation, 2009).

b. What is the policy

Speed limits are changed in correspondence with the re-evaluation of non-statutory speed limits, and this evaluation is recommended to happen at least once every five, seven, or ten years on roadways that have had significant change in characteristics or surrounding land use since the previous evaluation. If it is found that there is a need to change the speed limit by 5 MPH or more, this decision must be justified via documentation and approved by a registered Civil or Traffic Engineer (California Department of Transportation, 2009).

c. Results of the policy

After these new standards for speed limits are set, data regarding the existing posted speed limit, the new posted speed limit, the 85^{th} percentile speed limit, and the 50^{th} percentile speed limit must be collected and evaluated over a twelve month period. For the new speed limit reduction to finally be in place, this data must be reviewed by the Caltrans Director, California Highway Patrol (CHP) Commissioner, and the California

Traffic Control Devices Committee (CTCDC) for any further changes. This data will also be reviewed in light of recent trends in new speed limits (California Department of Transportation, 2009).

V) ***Political Acceptance***

a. *Political acceptance/resistance to the strategy*

Political attitudes toward speed limit strategies have changed over the last few decades and are influenced by factors beyond GHG emissions and fuel consumption. In the 1970s, there was significant political support for the 55 MPH speed limit recommended by President Nixon in response to the ongoing wars and energy crisis. This resulted in measures for the national speed limit being overwhelmingly passed in both the House of Representatives and Senate (1990). More contemporary attitudes toward speed limit reductions are less supportive, and there have been pushes to increase the national speed limit to 70 MPH or higher, with individual states going as far as raising the speed limit to 70 MPH on their own. In Maryland, for example, the push for the 70 MPH speed limit has been motivated by great public support and the belief that higher travel costs, such as from tolls, warrant increased speeds. Ultimately, these current measures are receiving bipartisan support despite concerns of greater fatalities and subsequent raised insurance costs (WBAL TV, 2013).

VI) ***Public awareness/education***

a. *Public acceptance/resistance to the strategy*

As a whole, there appears to be public resistance toward any strategies that enforce speed limit reductions. A study in Australia by Archer et al. (2008) revealed that 33% of residents in Victoria lowered their driving speed in response to a speed limit reduction while 61% of drivers stayed at the same speed, despite 83% of residents believing the speed limits were set at reasonable levels. Another study in Japan by Dinh & Kutoba (2003) demonstrated that 57% of surveyed drivers admitted to breaking the speed limit often or very often and only 2% stated that they never exceeded the speed limit at all. Dinh & Kutoba also found that drivers were unlikely to view speeding as socially unacceptable, believing that occasionally speeding on 30 km/h (19 MPH) zones beyond the speed limit was acceptable. Similar to Archer's study, a majority of respondents (66%) felt that a posted speed limit of 30 km/h (19 MPH) was reasonable despite the resulting speeding trends. A study by Elliot et al. (2005) tries to explain this driving behavior by stating that compliance with the speed limit is not necessarily a driver's intention; rather, compliance with speed limits is a result of drivers' attitudes, particularly the attitude that following the speed limit will result in less fuel usage.

b. *Public issues/concerns regarding the strategy*

The public's lack of adherence to speed limits is primarily an issue of deteriorating enforcement, with increasing proportions of motorists routinely exceeding speed restrictions on non-urban roads (Fergusson, 1994). There are different approaches to speed limit enforcement across the world, each with varying degrees of success. Soole, Watson, & Fletcher (2013) found that all types of camera strategy resulted in reductions in average speeds. In particular, Australia and Europe have found much success with average speed enforcement. For this strategy, cameras are installed on multiple locations along a road, and vehicles that pass through the first camera site have vehicle registration data captured. If the average speed of the vehicle exceeds the legal posted limit speed limit when it passes through the second camera site, this data is sent to a central processing unit for further review (Soole, Watson, & Fletcher, 2013). As a result of average speed enforcement, it has been found that offence rates are usually less than 1%, even when daily traffic volumes are high (Soole, Watson, & Fletcher, 2013). Meanwhile, police enforcement in the United States has experienced mixed results. While police enforcement reduced the percentage of speeding drivers from 30% to 20% during certain intervals of the day (particularly between 12 am to 6 am), it has been found that other times of the day, such as morning rush hour, were more resistant to police enforcement (Vaa, 1997). While a camera-based strategy appears objectively better, any sort of maintained enforcement strategy will ultimately yield benefits in reducing driver speed.

VII) Other items not noted above, but relevant to Caltrans and GHG reductions

N/A

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APPENDIX F: VMT MATRIX

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Transportation Land Use Planning						
Residential density *ARB brief	Higher density is encouraged through infrastructure, zoning, and public finance policies that focus development around transportation nodes or raise land prices, thus encouraging smaller lot sizes. Higher density may reduce VMT, and consequently, GHG emissions.	Doubling residential density is associated with a 5-12% VMT reduction. Based on two scenarios -- 25% of all future new residential development is twice the average density of new development in 1990s, and 75% of future new development is to be twice the 1990s density level -- it is estimated that GHG emission reductions will range from 1-11% below baseline trends in 2050.	2. Moderate (VMT reduction impacts are higher in areas with greater regional access to jobs than areas that are further from job centers or other travel destinations.)	Elasticity of VMT with respect to residential density ranges from -0.05 to -0.12.	2. Moderate (There are two methodological issues. First, people may live in higher densities because they want to drive less, so high density does not necessarily reduce VMT directly. Second, there may be large differences in travel choice due to high density land use, such as residents choosing to walk rather than drive.)	2. Moderate: Some compulsion, low cost (Higher density infill development is increasingly common and can range from one parcel to larger plans. Prior to the recent housing downturn, urban areas throughout California felt pressure from high land prices to increase density through smaller lot sizes or urban infill.)
Transit access & Transit-oriented development (TOD) *ARB brief ***Ewing	Transit agencies increase transit access by providing new services or rerouting services to new areas, and bringing transit closer to potential users. Transit access also increases when greater housing and land use density creates shorter walking distances to transit stations, known as transit-oriented development (TOD). Transit access is also affected by street and network design.	There is an estimated 1.3-5.8% decrease in VMT per mile closer to the station. This effect is likely to occur only within 2 miles of a rail station and 0.75 miles of a bus stop. However, there are no studies that provide direct evidence of the effect of transit distance on GHG emissions.	2. Moderate (VMT and GHG reduction impacts would be dependent on the nature of the trip and whether available transit is interregional or regioinal.)	*** Elasticity of VMT with respect to the distance to the nearest transit stop = -0.05	3. Low: More research is needed to link VMT reduction evidence from TOD with GHG reduction.	2. Moderate: Policies that support TOD are common in California, especially in the San Francisco Bay Area and the Los Angeles region. The Metropolitan Transportation Commission has adopted a policy that sets standards for minimum levels of development around transit stations.
Demand management **FHWA	Demand management refers to a set of strategies to reduce single occupancy vehicle travel, including addressing externalities such as GHG emissions. Some strategies are aimed at reducing total travel demand while others are aimed at reducing peak period demand. These strategies include road pricing, parking management/pricing, car sharing, pay-as-you-drive insurance, ridesharing, transit incentives, transit improvements, and telework	Demand strategies have the most significant effect on GHGs when emissions from driving are high, but no specific data is given.	2. Moderate (interregional impact depends on the demand strategy used)	Not found in literature reviewed	2. Moderate: It is unclear if people participate in demand management programs because they prefer to drive less or because the demand management program itself encourages people to drive less.)	2. Moderate: Demand management, as a whole, represents a "carrot-and-stick" approach. These strategies can reduce demand and generate revenue, but they are socially and economically controversial since they add expenses to households and businesses and may result in an inequitable distribution of expenses. These consequences are greater when drivers have limited alternatives to single-occupancy vehicle driving.
Smart growth *ARB brief ***Ewing	Smart growth encourages mixed-use neighborhoods that offer employment, shopping, and recreational opportunities within short distances of residences, and encourages infill development. Smart growth can faciltiate non-automobile travel modes, shorten car trips, and consequently reduce GHG emissions.	A 1% increase in land use mix decreases average VMT between 0.02 and 0.11 percent. Per capita CO2 emissions is approximately 13% lower in neighborhoods in the highest 20% of land use mixing index values compared to neighborhoods in the lowest 20%.	3. Low (mixed-use neighborhoods are on a smaller scale than interregional travel. Some interregional travel may be reduced if residents do not travel interregionally for work and shopping.)	Elasticity of VMT with respect to land use mix is -0.02 to -0.11. *** Elasticity of VMT with respect to land use mix = -0.09	1. High: A potential weakness is that studies do not account for residential self-selection, i.e., people choose a residential location based on their transportation preferences. However, even without controlling self-selection, there is a likely direct impact of land use mix on VMT.	See TOD and infill

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Transportation Land Use Planning						
Regional accessibility *ARB brief ***Ewing	Regional accessibility is the ease of destinations being reached throughout a region. In general, residences closer to the regional center have higher levels of regional accessibility since there is a greater concentration of jobs and activities. Subcenters also contribute to regional accessibility.	VMT reduction estimates range from -0.05 percent to -0.25 percent per 1 percent increase in regional accessibility. There are no studies that provide direct evidence of the effect of regional accessibility on GHG emissions.	3. Low	Elasticity of VMT with respect to regional accessibility ranges from -0.05 to -0.25. *** elasticity of VMT with respect to job accessibility by transit = -0.05	2. Moderate: Cities studied represent regional accessibility in a simplistic manner, not accurately capturing increases/decreases in VMT for variables such as jobs accessibility. In addition, most studies use travel distance rather than travel time, which omits the impact of congestion.	3. Low: Regional accessibility is difficult because it requires coordination between many jurisdictions within a region, and it may lead to competition between transit networks. Simultaneously, regional accessibility has helped drive redevelopment efforts to revitalize downtown areas into mixed-use centers.
Job-housing balance *ARB brief	Jobs-housing balance is based on premise that the decreased distance between residence and work locations will reduce people's travel distance to and from work. There is not enough evidence to link VMT reduction from jobs-housing balance with GHG reductions.	1% increase in jobs-housing balance is associated with a VMT reduction between 0.29-0.35 percent, but there are no associated GHG estimates based on original travel studies. Some studies base estimates on agency reports that are no longer available, such as SANDAG's estimate that jobs-housing balance decreases GHG emissions by <2% and VMT between 5-9%	4. Very Low (jobs-housing balance operates over a smaller spatial scale than regional accessibility, and most studies on jobs-housing balance look at distance of approximately 4 miles)	Not found in literature reviewed	3. Low: More research is needed to link VMT reduction evidence from jobs-housing balance with GHG reduction.	1. High: California Assembly Bill 2864 and associated legislative efforts provided funds for integrated jobs-housing balance planning efforts within eight metropolitan areas, as well as competitive grant funding for municipalities to support capital projects associated with increase in housing units.
Infill **FHWA *ARB brief	Infill encourages growth on former industrial sites and is also known as brownfield development. Infill is often incorporated in smart growth and residential density strategies.	See residential density	4. Very Low	Not found in literature reviewed	N/A	2. Moderate: Higher density infill development is increasingly common and can range from one parcel to larger plans. Urban areas throughout California have felt pressure for increasing density through smaller lot sizes or urban infill.
Pedestrian oriented *ARB brief	Improving walking environment can also reduce VMT, but only if it replaces travel by car. Strategies include improved & expanded infrastructure, enhanced security and comfort on streets, traffic calming, walking programs, and programs to promote safe travel behavior. Walking for utilitarian purposes impacts VMT, but walking for recreational purposes does not. Residents of traditional and new urbanist neighborhoods walk more than residents of conventional, suburban neighborhoods.	There is a 0.09 to 0.27 percent increase in walking per 1 percent increase in sidewalk coverage, length, or width. Another study found that 72% of walking trips to a store replaced driving trips; the estimated monthly VMT savings was 2.1 miles per person. In a third study, the presence of sidewalks was associated with a 0.14 percent decrease in vehicle trips. Other studies found no effect. In new urbanist or traditional neighborhoods, VMT decreases ranged from 20-24 percent. No studies provide direct evidence of the impact of pedestrian strategies on GHG emissions.	4. Very Low	Not found in literature reviewed	3. Low: Many studies focus on university students and employees in small cities, and therefore, results may not be relevant to larger cities. In addition, walking represents a small share of all daily travel, so large increases in walking may lead to small decreases in driving. In addition, walking may be replacing transit or bicycling rather than driving.	3. Low: (Efforts are pushed by public health officials, but the impacts of pedestrian improvements and other pedestrians trategies are rarely evaluated.
Safe routes to schools *ARB brief	Part of "pedestrian-oriented strategy," which can help reduce VMT by improving the walking environment	not found in the literature reviewed	4. Very Low	Not found in literature reviewed	3. Low: Walking represents a small share of all daily travel, so large increases in walking may lead to small decreases in driving. In addition, walking may be replacing transit or bicycling rather than driving.	3. Low: Supported by public health officials, but the impacts of pedestrian improvements and other pedestrian strategies are rarely evaluated.
Network Connectivity *ARB brief ***Ewing	Network connectivity is the quality of the connections that link points in a community to one another. The street network (street and intersection patterns) determines the directness of connections. Connectivity can both reduce and increase VMT.	Studies have found that a 1% increase in connectivity can result in a change in VMT ranging from -0.19% to 0.46%. No available studies provide direct evidence on the effect of connectivity on GHG emissions.	4. Very Low (street connectivity studies have primarily focused on residential areas and short-distance trips.)	*** Elasticity of VMT with respect to intersection/street density = -0.12	**4. Very Low** (Estimates have notable limitations. The estimated effects in all studies are based on a comparison between neighborhoods rather than changes in VMT that result from a change in connectivity. In addition, the studies use different connectivity variables rather than controlling for some factors.)	3. Low: Significant $ & time public/private, various players (While numerous cities have adopted changes in their subdivision ordiances to promote greater connectivity, retrofitting communities is challenging in comparison to requiring high levels of connectivity when a neighborhood is first built.)

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Transportation Alternatives						
Intercity passenger bus and rail (CCAP: bus rapid, light rail, ULI: high speed rail) **FHWA	Intercity passenger bus and rail is a part of a larger transit expansion and improvement strategy that seeks to create new routes, increase service frequencies, and increase comfort of transit.	The range of possible reductions from investments in intercity and high-speed passenger rail is 0.4-1.1% of total GHGs from on-road transportation in the US.	1. High	Not found in literature reviewed	4. Very Low: As with local transit expansion, increased transit service through intercity passenger bus and rail does not guarantee increased use, and some regions have seen decreases in ridership after increased service. In addition, many forms of transit improvements (such as more vehicles, more lines, etc.) can produce GHG emissions.	4. Very Low: As with local transit expansion, intercity rail and bus can be costly, controversial, and may not produce anticipated ridership gains. Building and operating transit improvements, or even expanding service, may not be financially viable.
High Speed Rail **FHWA	High speed rail is a part of a larger transit expansion and improvement strategy that seeks to create new routes, increase service frequencies, and increase comfort of transit over long distances.	The range of possible reductions from investments in intercity and high-sped passenger rail is 0.4-1.1% of total GHGs from on-road transportation in the US.	1. High	Not found in literature reviewed	4. Very Low: As with local transit expansion, increased transit service through high-speed rail does not guarantee increased use, and some regions have seen decreases in ridership after increased service. In addition, many forms of transit improvements (such as more vehicles, more lines, etc.) can produce GHG emissions.	2. Moderate: As with local transit expansion, high-speed can be costly, controversial, and may not produce anticipated ridership gains. HSR planning in California has been funded and is proceeding.
Ridesharing **FHWA	Ridesharing involves increasing vehicle occupancy, and strategies include outreach programs and services to increase carpooling and vanpooling,	The effects of ridesharing on GHG emissions cannot be generalized since emissions effects vary depending on the policies and strategies used. Metropolitan Washington D.C.'s integrated ridesharing programs reduced vehicle trips by 5,600 and reduced 146,000 VMT per day, leading to a potential reduction of 62 MTCO2 per day. In Atlanta, carpooling and ridesharing reduced total daily trips by 8,170 and a net daily VMT reduction of 218,000. In the state of Washington, a trip reduction program reduced VMT by 170 million per year and emissions by 85,700 MTCO2 per year.	2. Moderate	Not found in literature reviewed	2. Moderate (The largest uncertainty is estimating the degree to which single-occupancy vehicle drivers respond to ridesharing incentives, since many factors can influence these decisions. Studies can also make assumptions about the unintended effects of ridesharing.)	2. Moderate: Some compulsion, low cost (Ridesharing and the associated budget is not treated separately from other commuter assistance programs. Washington DC's annual budget for ridesharing is $5.2 million, and many regions are operating on even smaller budgets. However, most regions do currently operate commuter assistance programs, and ridesharing is considered a widely accepted strategy.)
Employer-based Trip Reduction *ARB brief	Employer-based trip reduction programs include employer-provided alternative mode services (carpool, vanpool, preferential parking, carsharing), financial incentives for reduced public transit fares, worksite facilities for physically active commuting (showers, lockers, bike racks), alternative work schedules, and transit promotion campaigns.	Washington State commute VMT was reduced by an average of 6% for employees participating in a law-mandated commute trip reduction program. A voluntary employer-based trip reduction program found similar VMT reductions between 4.16-4.79%. Overall, employer-based trip reduction programs can potentially reduce VMT for employees at participating work sites between 4-6%. In Washington state, employer-based trip reduction programs reduced CO2 equivalent emissions between 0.2-0.6%, and other simulation models show a reduction between 4.11-4.74%.	2. Moderate (impacts depend on whether or not interregional commute will be affected by employer-based trip reduction programs.)	Not found in literature reviewed	3. Low: There is no evidence of the effectiveness of mandated trip reduction programs for work sites smaller than 100 employees, and evidence shows that smaller worksites are less likely to use alternative mode services such as vanpooling. Employer-based trip reduction programs may also cause induced travel, resulting in a VMT reduction for a region that is lower than commuting VMT at participating work sites. Most studies on trip reduction programs don't use control groups.	2. Moderate:The South Coast Air Quality Management District implemented a commute trip reduction program, and Assembly Bill 2522 developed a commute trip reduction program that was implemented in late 2009 as Rule 9410. In addition, firms are incentivized to design their own employer-based trip reduction programs.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Transportation Alternatives						
Telecommuting *ARB brief	Telecommuting allows employees to work from home and communicate with their regular workplace via email, telephone, or video-conferencing. Employees can also work at a telecenter close to home.	Theoretically, telcommuting should reduce total VMT by 100%, but it has been found that a reduction by 90.3% is more likely due to some work-related trips that employees must make while at home. Telecommuting from a telecenter reduces VMT between 62.0-77.2%. No studies provide direct evidence of the impact of telecommuting on GHG emissions, though several studies estimate the effect on energy use. For example, the Federal Highway Administration estimated a savings of 1.72 gallons for each telecommuting day, assuming an average roundtrip commute distance of 34.8 miles and an average fuel economy of 20.3 miles per gallon (mpg).	2. Moderate (impacts depend on whether or not interregional commute will be affected by telecommuting.)	Not found in literature reviewed	2. Moderate: Studies do not account for other employer policies, such as parking fees or transit subsidies, that might impact the effect of telecommuting. In addition, time saved from telecommuting may result in trips for other purposes.	1. High: Congress passed the National Air Quality and Telecommuting Act that established a market-based pollution-credit program to encourage telecomuting. Federal funding has been given to employers to begin or expand telecommuting and these efforts have formed partnerships between employers and state, regional, and local agencies.
Local transit expansion, promotion, service improvements (Increased Levels of Service/Improved Travel Times, expand) *ARB brief **FHWA	Transit improvements consist of creating new routes, increasing service frequencies, or increasing the comfort of transit in order for transit to gain a higher share of trips.	It is estimated that transit capital investments across the U.S. can reduce CO2 emissions between 144-575 MTCO2 cumulatively by 2050. BART, for example, was estimated to reduce 1000 MTCO2 per year by increasing off-peak train frequency. A 10-mile extension could reduce GHG by 38,000-111,000 MTCO2. Policy brief has a contradictory perspective: "The effects of transit strategies on greenhouse gas (GHG) emissions are unknown." Studies suggest that a 1 percent increase in service frequency will lead to a ridership increase of approximately 0.5 percent, that a 1 percent increase in service hours or miles could lead to a higher increase of around 0.7 percent and that a 1 percent decrease in fares will lead to about a 0.4 percent increase in transit ridership.	3. Low (local transit expansion and improvements operate on a more regional scale than an interregioinal scale.)	Not found in literature reviewed	4. Very Low: The issue of self-selection makes it difficult to draw conclusions about the GHG impacts of transit improvements. Increased transit service does not guarantee increased use, and some regions have seen decreases in ridership after increased service. In addition, many forms of transit improvements (such as more vehicles, more lines, etc.) can produce GHG emissions.	4. Very Low: Transit improvements can be costly, controversial, and may not produce anticipated ridership gains. Building and operating transit improvements, or even expanding service, may not be financially viable for many agencies.
Non-motorised transportation (bike) *ARB brief	Bicycle strategies fall under two categories: infrastructure improvements projects and programs that promote bicycling directly or indirectly. Other stragies seek to facilitate bicycling in combination with transit.	Bicycling has an impact on VMT when it is used for utilitarian purposes rather than recreational purposes, thus replacing a driving trip. However, there have been no studies that provide direct evidence between bicycle strategies, VMT and GHG emissions. A 1% increase in perceived bicycle parking availability is associated with 0.83% increase in the probability of bicycling and a 0.01% decrease in the probability of driving. A 1% increase in bicycle lane miles or federal funding on bicycle/pedestrian infrastructure is associated with a 0.32% increase in city bicycle commute.	4. Very Low	Not found in literature reviewed	4. Very Low: There are no studies that provide direct evidence between bicycle strategies, VMT and GHG emissions. Despite growing popularity, bicycling represents a very small share of daily travel, so its impacts may be small as well.	2. Moderate: Some cities, such as Portland, have seen dramatic increases in bicycling through various infrastructural strategies based on European ideas. The city also invests in promotiional activities, education, marketing, and harmonization between bicycling and public transit.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Transportation Alternatives						
Fare Measures **FHWA	Transit agencies can incentivize transit use by offering discounted or free fares to all riders, either on a permanent or promotional basis. Transit agencies have implemented strategies that focus specfiically on offering discounts to employees/commuters.	Unlimited ride passes, which reduce the amount of fare a traveler pays within a time period, can reduce 85,000 MTCO2 annually on BART. Free fares for children riding BART on Saturdays can reduce 15,000 MTCO2 annually.	3. Low (public transit tends to operate on smaller scale, such as regional as opposed to interregional.)	Not found in literature reviewed	The effect of increased ridership on CO2 reductions depends largely on the previous mode of transportation.	3. Low: Discounted and free fares through universal pass programs have resulted in increased transit ridership at universities. BART has considered free transit fares for children on Saturdays. However, agencies facing deficits are likely to consider rasing fares, especially since half of agency operating revenues come from sources other than fares. Transit agencies are also likely to tighten discount programs for financial reasons
Carsharing **FHWA	Car sharing promotes a model in which participants rent vehicles on an as-needed basis, and may forego owning their own vehicles.	Emissions declined between 0.8-1.2 MTCO2 annually per member, even after accounting for carsharing members that drive more frequently. A household reduces 0.84 MTCO2 per year after joining carsharing.	3. Low (effective carsharing tends to be limited to compact neighborhoods or areas with limited parking.)	Not found in literature reviewed	2. Moderate: It is difficult to establish a control group for studying GHG reductions from carsharing since carsharing is voluntary. It is also difficult to estimate its potential growth since it is relatively new.	1. High: Car sharing does not require major infrastructure investments or adoption of new technology by the public sector. Public agencies may also provide subsidies for
Pricing System Use						
VMT fees (Road user pricing) *ARB brief **FHWA	This transportation demand management approach is a charge requires users to pay for access to a roadway segment such as a toll road or bridge. Other approaches include cordon pricing and distance charging.	Models of a national distance charge for England predict a 9-19% reduction in VMT for several pricing scenarios based on existing road and rail transpotation price elasticities. In California, a 10% increase in driving costs from a VMT charge would result in a 2.5% decrease in driving distance. Where road pricing has been employed in practice, before-and-after studies have found that VMT was reduced by between 2 and 10%, and, where measured, GHGs declined by 2 to 6%. One study estimated that the London congestion charge resulted in a 19.9 percent reduction in CO2 emissions inside the charging zone. According to another study, CO2 emissions can be reduced by 18% through congestion tolls on freeways in Santa Clara County, assuming distance charge is $0.18 per mile.	1. High	Sensitity of traffic volume to price changes, in terms of elasticities, fall within -0.1 and -0.45.	2. Moderate: Evidence quality for distance charging is lower than other forms of charging due to the lack of current programs. Estimates are also limited by non-random samples and the assignment of certain household types to the control group.	3. Low:
Intercity tolls (cordon pricing) *ARB brief	Under cordon pricing, drivers are charged when crossing the boundary of a predefined tolling area. Cordon tolls are generally suitable for travel demand management in central business districts of major cities, where congestion and pollution mitigation are desired and where trip substitution using other modes is feasible	Traffic reductions between 12-22% have been achieved through cordon pricing in five major European cities. In Singapore, traffic volume is expected to decrease 2-3% for every 10% increase in cordon charges.	1. High	Not found in literature reviewed	1. High: cordon charges assess traffic flow reductions by looking at vehicle counts while other factors are controlled to effectively isolate toll prices on traffic volume.	4. Very low in the United States
Pay-As-You-Drive (PAYD) Insurance **FHWA	PAYD allows drivers to purchase insurance that varies based on the amount of miles driven. PAYD turns fixed insurance costs into variable costs where drivers save money by reducing the amount they drive.	There are no overall figures regarding GHG reductions from PAYD, but modeled and empirical data reveal that VMT is reduced 5-10% per vehicle/policy. Assuming PAYD reduces VMT by 5%, passenger cars can save 26 gallons of gas and 510 lbs of CO2 annually, and light trucks can save 30 gallons of gas and 595 lbs of CO2 annually.	1. High	Not found in literature reviewed	2. Moderate: The primary uncertainties with PAYD implementatioin is how quickly this form of insurance will spread throughout the marketplace, and the degree in which drivers reduce their VMT due to PAYD.	2. Moderate: Costs to public agencies in order to implement PAYD is minimal since no extra infrastructure needs to be built. However, there are issues regarding state insurance policies, privacy, and enforcement.

Strategy	Qualitative Summary	Quantitative Summary	Interregional Impact	Elasticities	Technical Acceptability / Level of Confidence	Political Acceptability
Pricing System Use						
Congestion pricing (real time, urban nonmotorized zone) **FHWA	Congestion pricing is aimed at reducing congestion by enacting higher fees during peak hours, and include high occupancy/toll (HOT) lanes, cordon tolls, and distance-based pricing.	Decreases in congestion and CO2 emissions from congestion and road pricing have not been consistent over time. A proposed regional HOT lane network in the SF Bay Area is estimated to lower CO2 by 7% during morning peak hours. Cordon tolls in eight mid-sized cities in England were expected to reduce CO2 between 1.4%-14.2%. Road-pricing systems in Copenhagen demonstrated a CO2 reduction between 1-3%.	2. Moderate	Not found in literature reviewed	2. Moderate: There are numerous factors that affect the estimated emissions impacts of road and congestion pricing, and the estimations vary depending on the type of road pricing used. For example, distance-based fares tend to produce greater reductions than cordon tolls or HOT lanes.)	4. Very Low: Cost estimates vary depending on location, technology, and type of implementation, and a single entity (such a state DOT or transportation authority) implements a road pricing system. However, road pricing has faced opposition from elected officials who believe that paying for trips that are typically free will raise equity concerns. There are also concerns regarding the potential for mode shifts as a result of congestion pricing, as well as privacy concerns regarding the installation of in-vehicle equipment.
Parking management (pricing, restriction, Municipal Parking Programs) *ARB brief **FHWA	Three different parking pricing strategies exist that can potentially reduce VMT and GHG emissions: long/short-term fee differentials, on-street fees and residential parking permits, and workplace parking pricing.	In terms of workplace parking, parking pricing policies can produce moderate VMT reductions among employees by accepting a parking subsidy cash-out. One study in California found a 12 percent VMT reduction among individuals who accepted a parking subsidy cash-out.	2. Moderate	Not found in literature reviewed	3. Low: The available evidence on the direct impact of parking pricing on VMT is relatively scarce. In addition, much of the evidence that does exist was obtained from studies that are now at least 15 years old. Further research needs to be done to determine how various parking pricing policies impact GHG emissions.	2. Moderate: Parking cash-out laws were enacted in California in 1992 that required employers in air quality non-attainment areas with 50+ employees to offer cash instead of a parking space.
Commuter Incentives (modal subsidy)	Commuter incentives make transit cheaper for riders through employer-based tax incentives that allow employers to reduce transit fares and special programs such as transit passes that decrease riders' costs.	The effect of commuter incentives on GHG is unknown, but could be potentially large.Transit benefits that were voluntarily implemented by employers demonstrated a 10% increase in the number of employees riding transit. Surveys show an increase in ridership that range from 10% to over 150%, with about half of surveys reporting increases between 10-40%.	4. Very Low (public transit tends to operate on smaller scale, such as regional as opposed to interregional.)	Not found in literature reviewed	3. Low: Transit agencies define their services areas differently and multiple operators often serve one region, which makes it difficult to objectively measure transit availability in a region. In addition, the effect of increased ridership on CO2 depends on previous modes of transportation that riders used prior to switching to transit. There are no known studies that measure how effective public sector efforts are in persuading employers to offer transit benefits.	2. Moderate: Barriers to implementation are low since they're voluntary for consumers, may be voluntary for employers, and employers receive a benefits package. Transit agencies pay costs to administer transit benefits programs, but there is a potential concern for loss of revenue despite transit agencies obtaining over half of their operating revenue from sources other than the fare box. Complications can also arise from the presence of multiple agencies involved in the implementation process.
Public Awareness						
Voluntary Travel Behavior Change (VTBC Programs) *ARB Brief	Voluntary Travel Behavior Change programs change traveler behavior by targetting their individual attitudes, goals and behaviors, increasing their awareness of travel choice impacts, and providing the skills to analyze and change their travel behavior.	12 TravelSmart programs in 9 cities resulted in a 8% reduction in car use among participants. TravelSmart in 3 cities in Oregon resulted in a 3-11% reduction in solo driving, correponding with a 9% VMT reduction. Relatively few studies have quantified greenhouse gas reductions. One estimated that long-term VTBC programs in three medium-sized English cities resulted in a citywide per capita carbon dioxide emission of approximately 50 kg -- equivalent to a 4.4 percent reduction in CO2 emissions from driving. Japan's 10 VTBC programs found a 19% CO2 reduction.	3. Low	Not found in literature reviewed	2. Moderate: Because VTBC programs are often implemented and evaluated by consultants that have been hired by local government, questions have arisen about potential lack of impartiality. Participating in VTBC programs is voluntary, and thus, effectiveness depends on the number of people who choose to participate.	1. High: Government agencies such as the Oregon Department of Transportation conducted a VTBC program, and were able to find participant households reducing their VMT by an average of 9%.

* California Air Resources Board: http://arb.ca.gov/cc/sb375/policies/policies.htm

** FHWA Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources. February 2012. Prepared for FHWA by RAND Corporation and RSG, Inc.

*** Ewing, Reid and Cervero, Robert. Travel and the Build Environment. Journal of the American Planning Association. May 11, 2010. http://dx.doi.org/10.1080/01944361003766766