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MTI MINETA TRANSPORTATION INSTITUTE

Congestion-Clearing Payments to Passengers

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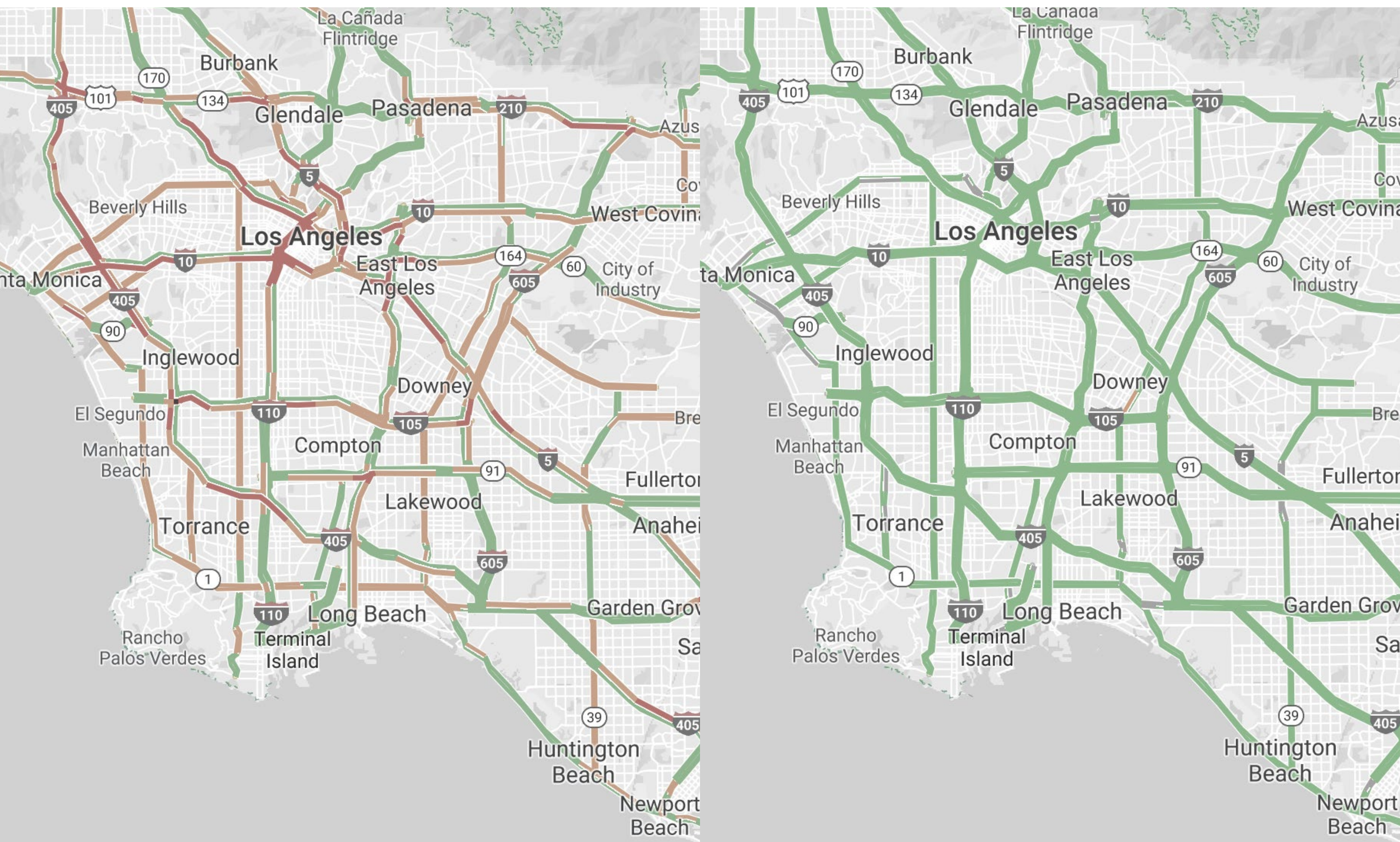

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REPORT 20-16

CONGESTION-CLEARING PAYMENTS TO PASSENGERS

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16. Abstract

Peak period motor vehicle traffic volume congests roads all over the world. This project hypothesizes implementing congestion-clearing payments to passengers as a permanent congestion-management solution. Ongoing congestion-free travel would be achieved by removing existing congestion, and absorbing (re)generated demand, at costs that would be expected to increase as the total number of travelers increases over time. The project develops a comprehensive, step-by-step methodology to calculate the benefits and costs of paying for drivers to become passengers at a congestion-clearing level and to maintain this level over time. The method is derived from the literature, analysis by the project team, and development of a case study. The case study, based on a long-standing bottleneck location in California, enabled the project team to think through the real challenges of developing and evaluating such a solution.

The project finds that the conceptual underpinning of the solution is sound. Based on a survey, the case study finds that there is a level of payment that could clear congestion and maintain free-flow for twenty years, with benefits that outweigh costs on a net present value basis by about four to one—though calibration is required. After the initial reward clears the queue at the bottleneck, a significant intra-peak demand shift would occur as existing and new travelers depart home at times that are more to their liking, potentially causing the queue to re-form. A second incentive manages time of travel, rewarding people for traveling as passengers earlier (or later) than the preferred high demand peak-of-the-peak. In the case study, the high proportion of people who say they will only drive alone would eventually result in some periods of single-occupant-vehicle-only traffic during peak, which is an unintended and undesirable consequence. For the case study route, a limit on single-occupant-vehicle travel during the peak-of-the-peak would ensure that high-occupancy-vehicle travel is given preference and would reduce the overall cost of the solution.

For the case study, the cost of the congestion-clearing payments-to-passengers solution on a net present value basis is within the estimated range of costs of the alternative of expanding the facility, and the benefits are expected to be greater than for facility expansion. Congestion-clearing payments to passengers can be implemented much sooner and will have greater positive long-term economic impacts. Facility expansion would provide lower and shorter-term benefits and would be expected to return to congested conditions within a year.

The project team proposes a pilot project on the case study route to test and calibrate the solution, as well as recommending development of further case study routes to find out how different routes vary and determine the causes of any variations.

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EXECUTIVE SUMMARY

In spite of years of congestion management effort, the use of highway systems around the globe reflects a tragedy of an overused commons. Peak demand jams up thoroughfares, consumes excess energy, and generates both localized pollution and greenhouse gases, not to mention travelers' time consumed and stress experienced while sitting in traffic. This project pursues the distinctly new concept of buying a targeted level of passenger travel by peak period commuters rather than providing more space in which to travel (as would be the case if road construction authorities incurred the cost of expanding infrastructure). Congestion-clearing payments to people who would otherwise be solo drivers—payments that serve to elevate the average occupancy of peak period vehicles—also represent a distinct and potentially more politically popular alternative for reducing congestion than setting road user fees that penalize travelers for driving in peak periods (congestion pricing).

This project explores and advances the concept of 'congestion-clearing payments to passengers' (CCPTP) as a potential solution to the challenge of reducing recurrent traffic congestion. In the process, the project encountered a minimal amount of prior thought about this approach, and the project team has had to conceptualize new methodology (referred to as 'the Method') as a result.

The Method outlines the data needed to evaluate a potential route, including a representative survey of the catchment population to:

- allocate commuters to usage groups of 'only drive, alone,' 'only drive but with passengers,' and 'travel as passengers';
- find out how travelers and non-travelers would respond to the removal of congestion; and
- establish the rates of payment required to incentivize people to travel as passengers, or to drive with passengers, in order to achieve different levels of congestion reduction.

The Method allows for estimating annual costs of the solution for twenty years into the future, as well as estimating annual benefits; discounting costs and benefits to the present; and deriving a benefit-to-cost ratio (BCR) and other relevant statistics for comparison with other approaches to solving the same congestion challenge. The project team characterizes the approach as a 'build-nothing-and-pay-passengers' alternative that can be included in project alternatives analysis and environmental reviews between the usual 'do nothing' and 'build infrastructure' options.

The project included choosing a case-study route and analyzing it to demonstrate how the Method could be used. The case study results are presented in this report. The results are encouraging—potentially clearing congestion at a long-standing bottleneck with a benefit-to-cost ratio exceeding 4.0 based on the present value of 20 years estimated benefits and costs discounted at 3%. See Figure 1.

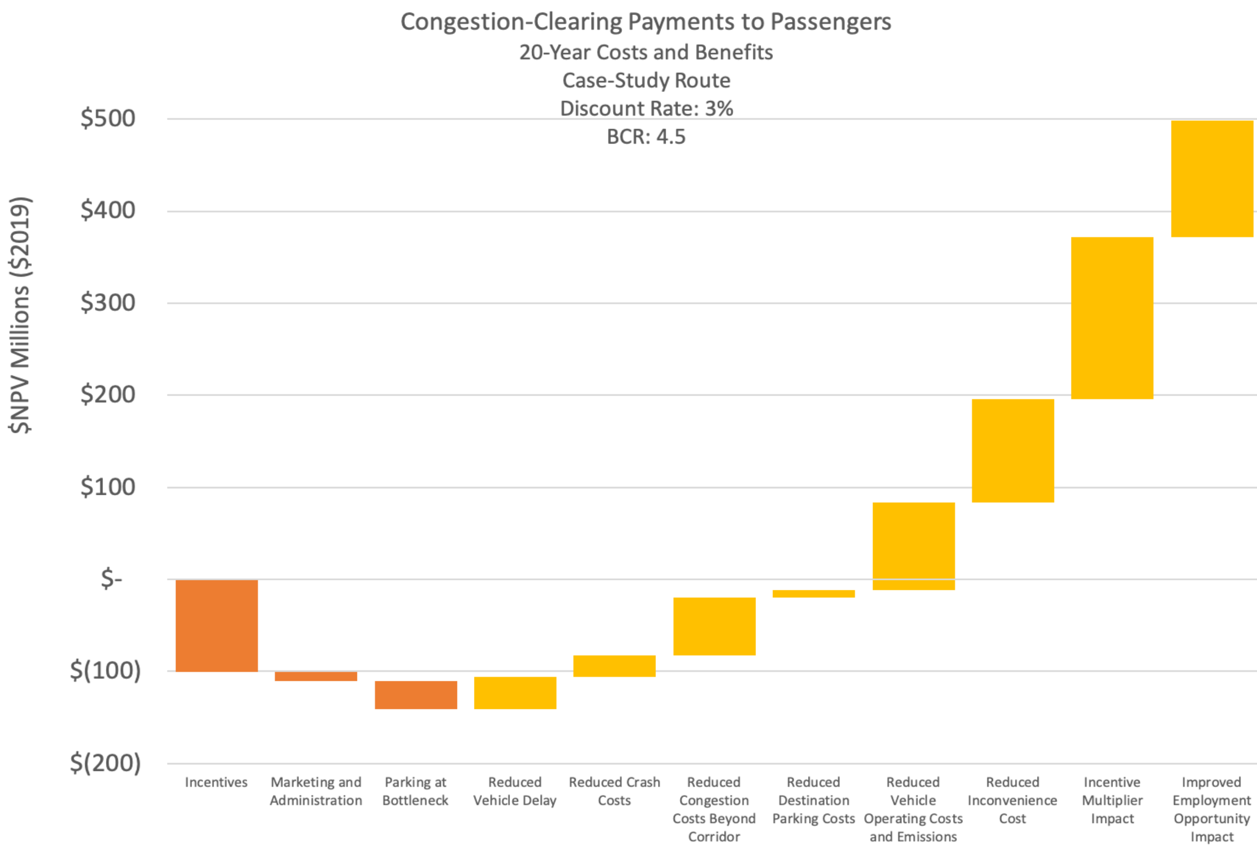


Figure 1. 20-Year Costs and Benefits

The costs and benefits so estimated are only estimates, and actual experience may or may not bear them out. The project team is keen to use the Method on other routes in order to develop an understanding of the range of potential benefit-to-cost ratio outcomes and to find out how much of the work is generalizable across different routes. The project team is also keen to test out congestion-clearing payments to passengers (CCPTP) by actually implementing it on a route (especially the case study route) in order to calibrate the estimates to actual results. The estimated cost of a five-year pilot project on the case study route is $40 million.

The key lessons learned from the study include:

- A new appreciation for the magnitude and impact of intra-peak demand shift that could occur when congestion is removed (specific to the case study, but probably generalizable). People's trip making will trend towards their preferred time of travel, which happens to be everyone else's preferred time of travel, and without time-of-travel-based bonuses to travel outside peak-of-the-peak, and limits on single occupant vehicle (SOV) travel during peak-of-the-peak, the congestion will re-form;

- Surprise about the lack of data that facilitate a true understanding of traffic congestion at a level that helps to manage it in the way the project envisages. Traffic queues form based on the minute-by-minute differences in the arrival and departure rate of vehicles at the bottleneck and grow as long as the one exceeds the other. Data collection about these arrival and departure rates, and the changing length of the queue, together with feedback processes to inform managers and travelers, could help to manage congestion;

- That the traffic reduction efforts are potentially limited by the proportions of commuters who would a) only drive, alone, or b) only drive, but with passengers, and c) travel as passengers. The greater the proportion of the first group, the higher the average occupancy required of the other vehicles on the route during the busiest periods. The greater the combined proportion of the first two groups, the lower the total congestion-clearing potential on the route.

- The need for a combination of incentives: first to shift drivers to being passengers, and second to encourage passengers to travel earlier (or later) than their preferred travel time.

- The probable need for a method to limit SOV travel during the peak-of-the-peak.

- The possible need for meeting-place-based parking near the bottleneck to simplify the higher occupancy vehicle formation whether in bus, van, or car.

The project team proposes investment in a pilot project on the case study route at a cost of $40 million over five years. The potential value of the solution, if it works as well with real commuters on congested roads as it does in the planning spreadsheets of this project, is many multiples of this investment on a nationwide and worldwide basis.

As the revisions to this report are being completed in April 2020, the impacts of Covid-19 are resulting in wholesale disappearance of traffic congestion around the world. It is possible to think that some changes will be permanent in the aftermath. The project team foresees two potential major trends that will have off-setting impacts on traffic congestion as the world returns to ‘normal’: reduction in use of public and shared transport due to concerns about future virus transmission; and reduction in commuter traffic as middle and upper management continue to work from home. The net effect is difficult to predict, in part because there might be lasting damage to economies depending on how long the disruption continues. Either way, the aftermath will be an ideal time to test CCPTP. The solution would distribute funds to people to help offset their losses from the disruption; and encourage, as soon as is appropriate, a return to shared transport as a mechanism for managing congestion.

I. INTRODUCTION

The purpose of the passenger-payments project is to develop a method (herein called 'the Method') for estimating the long-term costs and benefits of a permanent program of paying people to travel as passengers, rather than as drivers, on a corridor-by-corridor basis—to reduce existing congestion in a corridor to a target maximum level of delay—taking into account the potential impact of suppressed demand for peak period travel and induced traffic.

The Method would be used to prepare a robust cost estimate for a technology-enabled 'build nothing (paying passengers)' alternative to be used when considering investments in infrastructure. This approach is of particular relevance in the run-up to automated vehicles and the possibility that new infrastructure investments in the 5-to-20-year timeframe could become stranded assets under some future scenarios such as low-fare robotaxis.[1] It would also be relevant for developing and evaluating proposals for making better use of existing infrastructure, and for decarbonizing transport. It might be less costly and more beneficial than other alternatives.

The idea of paying incentives for people to switch modes or time of travel has been around for many years. Programs are generally short-lived, and often the participants revert to their original practice at the end of the program.[2] Such programs are usually targeted at a small number of travelers, and the payment amounts are relatively small.

While originally discussed by Vickrey in 1967, the idea of payment of incentives at congestion-clearing levels of payments has received little attention. Each decade, there seems to have been some work on expanding the use of incentives: for example, estimating elasticities for ridesharing incentives and parking charges in 1993,[3] peak-avoidance research in the Netherlands in 2009,[4] incentives experiments in Bangalore in 2009,[5] and the larger-scale San Mateo County Carpool Incentive Pilot Program in 2018.[6] Reports in 2010 explored the positive nature of paying incentives rather than charging tolls. Additionally, in 2018, the FHWA published a compendium of examples of incentives used to expand traveler choices.[7]

The idea that incentives should be part of the solution to traffic congestion therefore seems to be well rooted, but no previous work has gone as far as considering it as a primary strategy and calculating the twenty-year net present value business case for comparison with the costs and benefits of alternative solutions.

For this project, a solution is envisaged (herein, the Solution Specification) that would be enabled by a smartphone application (herein, the App). The App would NOT be used to arrange rides, but rather, using the App, a highly reliable record would be created whenever a person travels as a passenger in a carpool, vanpool, or bus, or by other appropriate congestion-reducing mode, recording the day, time, location, direction and distance of the trip. Other apps might be used to arrange rides, or other non-app mechanisms might be used, such as riding with co-workers or neighbors, or turning up to a flexible carpooling meeting-place.

The record of the passenger trip created by use of the App would be used (likely in real time) to generate a reward to the passenger, which could be in the form of cash, points, prize draw entries, or some combination of these items as set by local business rules for the solution, on a corridor-by-corridor basis. The amount of the incentive could differ for different days of the week, times of the day, and location and direction of travel in response to differing levels of demand and targets for congestion-reduction.

This solution can be seen as the diametric opposite of a congestion toll. Congestion clearing payments would amount to purchase, by the transportation authorities, of socially useful behavior from commuters who are selling their efforts to find and use decongesting modes, rather than—as in a congestion toll—decongestion being sold to people who choose congesting modes.

The critical difference between this initiative and previous incentive programs is that this solution would be implemented on a permanent basis. The amount of the payment would be incremented as needed to remove current excess traffic first, then to remove a volume equal to any suppressed demand as traffic refills the spaces vacated by the current excess traffic, and finally to remove a volume equal to any induced demand as it occurred due to economic growth or other changes in the corridor.

The solution would be implemented in highway corridors with significant peak period commuting delay. The availability of the incentives would be marketed to local commuters, along with details of the local business rules. The App would be made available for free to capture trip details and facilitate payments. The starting incentive would be analytically determined and then dynamically adjusted as necessary in response to the impact that it had. If the initial incentive were correctly chosen, it is expected that within a few months enough people would have switched to being passengers that the traffic would be reduced to the target level. If the target were not immediately met, the incentive on offer would be raised and would continue to be raised until the target was achieved. This approach reflects an underlying behavioral economics assumption that people are price sensitive and more people would respond to higher incentive offers.

Once the initial mode shift had occurred, and people could see a corridor with reduced congestion, it is expected that people would change their trip start times or modes or routes to refill the spaces created: this change reflects suppressed demand for peak period travel. In response, the Solution Specification would require the incentive to be raised sufficiently to again return to target congestion levels. This cycle might happen a few times until all the suppressed demand for peak period travel had been accounted for.

In the following months and years, the incentive would be adjusted dynamically (up or down) to reflect changes in the total level of person-trip demand and to maintain the target level of traffic. The management process for setting the incentive would eventually rely on machine learning and external datasets to ensure that the incentive on offer was always the most optimal for the expected traffic conditions on a given day.

If these mechanisms hold true, the demand for travel would be decoupled from the amount of traffic. The amount of traffic would tend to become constant, and average occupancy would rise or fall with changing levels of travel demand.

A major challenge for bringing such a concept forward—and testing it in a real environment—is the lack of an accepted method for estimating its costs and benefits. When planning to expand infrastructure, there is a long-standing method for calculating benefits and costs. If an alternative approach is to stand alongside the infrastructure expansion option, it will require some discipline, sophistication, and robustness to help compare what might be seen as apples with oranges and respond to the inevitable questioning by the promoters of the expansion option.

The project followed a research approach of brainstorm, literature search, qualitative research (focus groups), quantitative research (survey), and analysis. The project team brainstormed the range of topics that might make up the Method. The resulting components of the draft Method and relevant topics are shown in Figure 2. The literature search needed to be quite comprehensive and cross-cutting to track down relevant research for each of these topics.

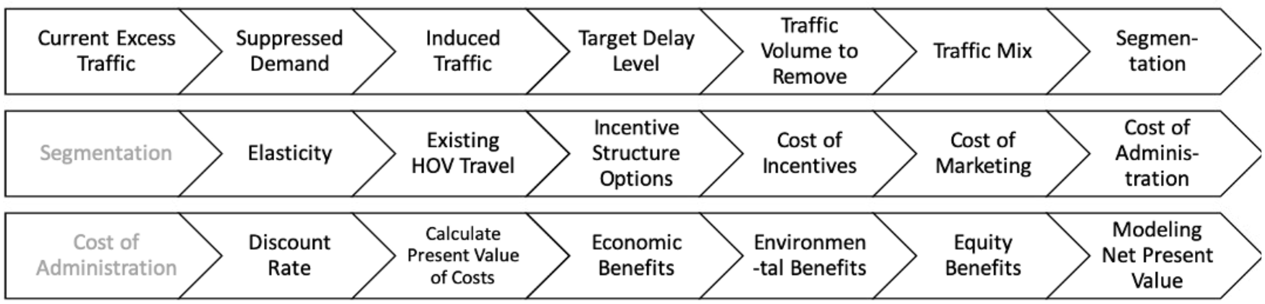


Figure 2. Components of the Draft Method for Evaluating Congestion-Clearing Payments to Passengers on a Route

The balance of this report is set out as follows: first, a review of the literature across the broad range of topics; second, a discussion of the potential method; third, a description of the project work including analysis of various components, plus the focus groups and the survey; fourth, the case study background and findings; fifth, a discussion about the various items of interest that the project raised; and finally, some conclusions and proposed next steps.

II. THE LITERATURE

To inform the project, the authors relied on literature related to paying passengers, quantifying excess traffic, and calculating generated traffic, among others. This review is reported next.

THE SOURCE OF AN IDEA: PAYING PASSENGERS

In 1967 Vickrey posited that it may be possible to pay travelers to adopt travel modes and times or even different routes that would avoid queueing.[8] In his calculation, he found that this payment approach would initially be the lowest cost option for decongesting the facility. However, he discounted it as a counterfactual that would be impractical to implement due to the difficulty of ascertaining who switched to a different mode or time or route and who just earned a reward by continuing an existing practice. Vickrey also claimed that while inexpensive in the beginning, such a practice could get extremely expensive over time. He concluded that congestion tolls constituted a strategy that would be easier to implement and monitor. Such tolling schemes, however, have been attempted in a very small number of locations, and they are politically challenging. Many people do not generally support the concept of charging tolls on formerly un-tolled roads as a congestion management tool.

Since the advent of mobile technologies such as smartphones with computer-based functional applications (apps), the technical hurdles have lessened significantly, and the provision of incentives and payments is much more administratively and technically feasible. Though there have been numerous studies related to Vickrey's congestion pricing framework,[9] there has been scant research into the possibility of paying for decongestion at a congestion clearing level rather than charging road users for this outcome. The beauty of buying decongestion rather than selling it in the form of tolls is that people would be paid for taking an action rather than being charged for a reduced state of congestion that may not materialize on any given day.

An incentive is in essence a negative toll, and the opportunity cost of foregoing an incentive is equivalent to a toll. In a toll situation, drivers who are 'tolled off' opt for other means of traveling or elect not to travel at all, which leads to reduced congestion. Paying people to travel as passengers has the potential to reduce solo driving trips and thereby similarly reduce congestion. Such a solution is well worth exploring, because, as stated thoughtfully by Dutch researchers, while "[a] reward system may be less effective than a tolling system … if tolling is politically infeasible a more relevant comparison is between a reward system and the absence of any control through financial mechanisms."[10]

CURRENT EXCESS TRAFFIC

Traffic congestion is a challenge that has continued to worsen for decades. It is also not limited to urban areas. Increasingly, ex-urban and rural places experience traffic congestion as well. The combined costs of traffic congestion across the USA were estimated to be $166 billion for 2017, up from $142 billion in 2012.[11] The 2017 estimate is reported to include 54 hours of yearly delay per auto commuter, a travel time index of 1.23, a freeway-only planning time index of 1.67, 21 gallons of wasted fuel per auto commuter, and a cost per auto commuter of $1,010. The 2017 traffic congestion therefore caused a total of 8.8 billion hours of delay, 3.3 billion gallons of wasted fuel, and $20.5 billion of excess truck running costs.

In spite of all this analysis the project team was unable to find any standard method for determining the amount of current excess traffic at a localized level. There is too much traffic, but there is no clear measure of how much too much traffic there is on any given route.

In his 1967 paper, Vickrey provided an example of a peak demand period of 90 minutes (with 4,400 vehicles per hour arriving at a bottleneck where downstream capacity was 4,000 vehicles per hour) that generated a queue of 600 vehicles that lasted two hours, with maximum delay to any one vehicle of 9 minutes, and average delay to all 8,000 delayed vehicles of 4.5 minutes.[12] The 'current excess traffic' in this Vickrey example is 600 vehicles, because if those 600 vehicles were not there at that time, there would be no queue and all the delay would be avoided.

The current excess traffic is therefore influenced by the speed at which vehicles arrive at and depart downstream from a queue of congested traffic at a bottleneck. Hutton explores the rate at which vehicles can pull away from the queue and finds that 1,800 vehicles per lane hour is a fair maximum to adopt for a good-quality road without impediments to normal flow such as signals, sharp bends, parked or turning vehicles, or pedestrian crossings.[13]

SUPPRESSED DEMAND AND INDUCED TRAFFIC

In the 1990s there was much discussion about whether the addition of road capacity 'induced' more travel, and similarly whether reduction of road capacity 'suppressed' travel. The use of both terms was generally intended as a measure of change in total daily traffic as a result of the change in capacity. Rescheduled departure times, where trips have been suppressed by congestion and then released in response to an initial reduction in congestion, are not seen in the literature as induced or suppressed traffic but rather as a 'return to peak.'[14]

Under very high levels of congestion, it is expected that any vehicles removed from the traffic will create spaces that will be immediately filled, demonstrating an overarching concept of generated demand that has a variety of names in the literature.[15]

The concept of 'return-to-peak' demand is described and quantified under an assumption of an increase in the amount of road provided (adding infrastructure) and the elasticity of demand to consume that added infrastructure, stated as the elasticity of Vehicle Kilometers (or Miles) Traveled (VKT) to lane-kilometers added, or VKT to generalized travel costs. Short-term elasticities have been found to range from 0.0 to 0.68 (increase lane kilometers by 1%, will increase VKT by 0.68%).[16]

Treatment of induced demand, where the amount of traffic increases due to economic growth that might itself be induced by the added capacity, is similar. Long-term elasticity of lane kilometers to VKT is found to range between 0.29 and 1.1.[17] In general, induced demand is expected to use up most of the new capacity within five years.[18]

The Victoria Transportation Policy Institute combines both types of demand under the heading of 'generated traffic' and refers to 'diverted trips' (changes in trip time, route and mode) and 'induced travel' (increased trips and trip length), finding that generally, the first year's generated traffic (after an expansion of capacity) represents diverted trips, while later generated traffic represents induced travel.[19]

Downs suggested that growing cities will always experience latent demand for roadways, demand that will emerge when capacity is increased.[20] In a principle he termed 'triple convergence,' Downs explained that the improved roadway will attract users who previously used different routes (spatial convergence); users who travelled during pre- and post-peak shoulder hours to avoid bottlenecks (temporal convergence); and users who previously opted for other modes (modal convergence). Downs lamented that "[o]nly road pricing or higher gasoline taxes are exempt from the principle of triple convergence."[21] That traffic tends toward equilibrium because of these protean factors makes it even more urgent to fathom "which transportation investment and management strategies provide the greatest social and economic payoff."[22,23]

REWARD SCHEMES ON THE ROAD

Given the potential for lasting impacts and providing a better taxpayer bargain than expanding a congested roadway, the notion of paying solo motorists to opt for a different travel mode has been tested in a few places around the world. Several of these programs have had promising results and provide a range of factors to consider when setting out to manage congestion. As Kelley points out, "[t]he old paradigm of simply building more roads to accommodate ever-increasing traffic should no longer be the only game in town."[24] Attempts to reduce peak congestion by using incentives have also been applied to peak hours on transit services.[25]

One of the most well-known schemes for rewarding road travelers for changing their travel patterns hails from the Netherlands. In order to reduce vehicle trips during peak periods, a group of Dutch universities, businesses, and government entities organized a 13-week long incentive program called "Spitsmijden" or "peak avoidance." As part of this initiative, commuters were rewarded with cash or credits toward a smartphone for shifting their travel time or mode. The results indicated that rewards can promote changes in travel patterns and may do so at greater levels than those achieved through road pricing, though the effects seemed to dissipate after the reward was eliminated.[26]

The elimination of a carpooling requirement in Jakarta provided an interesting case study for the network benefits of carpooling. For over twenty years, Jakarta required at least three people in the car in order to access the HOV lane during peak periods on arterials into the central business district. When the program abruptly ended in 2016, it provided an excellent opportunity to study the effects of the policy and its elimination. The traffic worsened considerably, even beyond the roads directly impacted by the policy.[27] The Jakarta analysis suggests that promoting higher vehicular occupancies can have network efficiencies beyond the time and location where they are in effect.

Various studies have shown that interventions focused on vehicle-occupancy can indeed reduce vehicle trips. Guiliano, Huang, and Wachs reviewed incentives from employers to improve average vehicle ridership in response to new regulations and found that financial incentives to switch from SOV to another option generated the most change across the two-year period studied.[28]

Prabhakar leveraged gamification to achieve a higher rate of participation at a lower cost per trip in a range of incentive programs to shift commuter trips away from peak periods. For example, the CAPRI (Congestion and Parking Relief Incentives) program at Stanford University used a custom-built mobile app and RFID sensors in users' cars to monitor arrivals and departures from campus. Users were given the choice between a) a small predetermined payment for each trip in which they arrived or departed from campus during pre- or post-peak shoulder hours, or b) foregoing the small, guaranteed amount in favor of an entry in a raffle with progressively higher likelihoods of payout for increased participation. The vast majority (87.3%) chose the chance to earn a higher prize, and this structure allowed the program to achieve average incentives of just 10 cents per person per trip. [29,30] Prabhakar explains that "when the stakes are small, a random reward is more appealing than a deterministic reward of the same expected value—a fact underlying lottery systems."[31]

Prabhakar also undertook an extensive peak-hour avoidance program experiment in Bangalore. Employees of a large company were incentivized to commute in off-peak times. Employees could again earn points toward a weekly raffle. The more frequently they avoided the peak hours, the more opportunities they had to win cash prizes. The number of employees commuting at off-peak times doubled under the program.[32]

Incentive programs have previously been considered in California. In the report *101 in Motion* prepared for Santa Barbara County, one of the proposals was to provide financial incentives to carpoolers and transit users to avoid the need to expand infrastructure.[33] Kelly (2007) proposed a payment of $10 per driver and $4 per passenger to convince a) 600 people to switch to being carpool passengers and b) 200 people to switch to being carpool drivers, and estimated that the annual costs associated with the incentive would still be about $1.5 million dollars lower than the maintenance costs of a proposed facility expansion of a new HOV lane.[34] Neither of these proposals was implemented.

The City/County Association of Governments (C/CAG) of San Mateo County, California, USA, piloted an incentive program in 2017/2018 that reduced the cost of using a specific carpooling app for passengers by $2 per one-way trip and increased the payment to drivers by $2 per one-way trip, up to twice per day—a total of $8 per vehicle-round-trip avoided.[35] The sum of one million dollars was allocated to the pilot program. Program reporting stated that it attracted 11,645 new users to the app, rewarded 907 average daily carpools, and provided 5 million rider miles. The project period ended before the funding was exhausted. Payouts totaled $843,000.[36]

The above C/CAG program was succeeded in 2019 by a new initiative called Carpool 2.0 that offered a significantly lower incentive: $2.50 per carpool day ($5.00 per vehicle-round-trip avoided), capped at $100 for the 15-month initiative.[37] After 10 months, the program reported that 2.5 million total miles (driver and passenger) had been recorded.[38]

The reporting for the two C/CAG programs does not show how many of the people who participated were new carpoolers, so it is difficult to ascertain the impact of the programs on regional congestion. At the time of writing, C/CAG officials are developing the specification for a new program called Carpool 2020. As of this writing, they continue to be actively interested in the use of incentives to help manage traffic congestion.[39]

FLEXIBLE CARPOOLING

An informal ridesharing solution involving about 7,500 commuters operates daily from Oakland, CA to downtown San Francisco, CA is locally termed ‘casual carpooling’. There are designated meeting places where during the morning rush at different times there might be a line of cars or a line of riders waiting to form 3- or 4-person carpools on a first-come, first-served basis with no prearrangement. A similar system existing in Washington, D.C., locally referred to as ‘the slug lines,’ also involves several thousand commuters daily. The Washington, D.C. instance is more complex than the San Francisco case because it involves multiple destinations as well as multiple meeting places.

These casual carpool/slug-line solutions have been in operation for over forty years, leveraging existing preferential high-occupancy vehicle (HOV) facilities (HOV lanes). While acknowledged by local transportation departments, they are non-official solutions that were not the result of research and development or innovation programs. Minett described these solutions as ‘flexible carpooling’ in an attempt to differentiate them from app-based carpool-formation systems.[40]

Traditionally no money changes hands in these solutions, but more recently the imposition of a toll for carpoolers on the Bay Bridge into San Francisco has resulted in riders making a contribution to the toll. No incentives are involved apart from the structural incentive of a HOV lane.[41] The systems are perceived by users as being safe to use, in part because each carpool has at least two passengers for one driver: people see strength in numbers.

Pearce and Minett patented a business process for a formalized version of flexible carpooling.[42]

SEGMENTATION

The idea of CCPTP raises the important question of whether a large enough fraction of commuters <u>would</u> travel as passengers if the incentives were sufficient. One study explored a segmentation methodology that looked at psychographic factors of people related to their trip-making. Seven segments were identified, of which only one, Car Lovers/Devoted Drivers, represented people who would be unlikely to respond to an incentive at any level. In three states across the USA, the other six segments, who would be positively disposed towards public transportation and carpooling and might respond to rewards, represented 80% (FL), 83% (OR), and 84% (VA) of total travelers.[43]

IMPACT OF INCENTIVES AND SURCHARGES

Research into Travel Demand Management methods in 1993 (the Comsis Report) gave estimates of the impact on commuter traffic of combinations of incentives for passenger travel and surcharges for single occupant vehicles (SOVs) in a series of tables that considered different configurations of urban density and mix of transit and rideshare modes.[44] The Comsis authors emphasized that their estimates would only be relevant if the incentives were available to all and SOV charges applied to all. The Comsis tables were updated for inflation in 2000 by the Victoria Transport Policy Institute (VTPI) and are currently available on the VTPI website.[45] In the VTPI update, the term ‘SOV surcharge’ was replaced with the term ‘parking charges,’ which—while not inconsistent with the intent of Comsis—leaves out other mechanisms that might exist for imposing surcharges on SOVs.

INCENTIVE STRUCTURES

People tend to value an entry in a prize drawing at a higher level than the probabilistic value of the ticket, especially when the prize is very large.[46] A one-in-one-thousand chance to win $1,000 should be priced at $1, but people may perceive it to be worth $2 or more. In the Bangalore experiments described earlier, a reward pyramid was used in which the size of prize was greatest, and the chances of winning higher, for people who participated most often and earned the most credits. Four levels of prizes were available, and a commuter who qualified at level 1 (highest) automatically qualified at all lower levels. Even though the prizes were relatively small, this mechanism encouraged greater participation.[47]

TECHNOLOGY

With respect to the technology aspects of the passenger-payments project, a number of providers in the USA and around the world are developing the capability to reliably capture information about passenger travel in cars, vans, or buses or other non-solo modes. Based on information in providers’ descriptive online marketing, from informal discussions with their executives, and from testing of some aspects of their smartphone apps by project team members, the team is confident that technology exists to provide high quality verification of mode, time, direction and distance of shared travel.

VALUE OF TIME

When calculating the benefits from congestion reduction (or the cost of congestion), standardized hourly rates tend to be used. As an example, in the 2019 Urban Mobility Report that calculates the cost of congestion across the USA, the Passenger Vehicle Motorist’s Value of Delay Time is an hourly rate of $18.12 per person hour (2017 dollars), and the value of travel time for commercial vehicles is $52.14 per hour (2017 dollars). The former is based on the median hourly wage rate for all occupations as produced by the Bureau of Labor Statistics. The latter is based on an annual survey of the trucking industry.[48]

JOB SATISFACTION BENEFITS OF REDUCED CONGESTION

English researchers in 2017 found that an additional 10 minutes (each way) of commuting time is associated with an equivalent impact on job satisfaction as a salary reduction of 19%.[49]

COMMONS GOVERNANCE

Roads and highways are one of the largest and perhaps most contested urban commons. Roads in North America are the most prevalent means of moving goods, services, and people from one place to another. In urban environments over many hours of usual work days, the demand for travel via personal automobile has outstripped the capacity of the commons to provide it, resulting in congestion and significant temporal and environmental costs. Often, the attempted solution to this problem has been to enlarge the facility, an option that is not always at play for a natural commons and is becoming less and less available for road commons. Minett suggests that rather than an engineering or supply problem, congestion is a behavioral problem attributable in part to a lack of effective commons governance among communities of users.[50]

The commons can be understood not just as a space, but also as a set of social processes expressed through relationships.[51] The social processes and relationships that govern expectations for mobility often privilege individual mobility without accounting for the ways that each individual on the road contributes to increased congestion. Emphasizing the social and environmental imperative behind shifting travel behavior can lead to more deliberate choices.[52]

A cautionary tale by commons researchers Van Vugt and colleagues in 1996 considered the highway commons and the implementation of a carpool lane in the Netherlands as a structural solution to the pervasive social dilemma of overuse.[53] They studied the opinions of solo drivers two months before and two months after the implementation of the new carpool lane, which would save users about 20 minutes travel time over the regular lanes, but of course involved a shift to a cooperative form of travel to enable access. They predicted that solo drivers would self-justify their existing choices to reduce psychological tension caused by establishment of the carpool lane. They noted in the study that the lane was closed within a year due to lack of interest and "enduring resistance among solo drivers."[54] The catalyst for the closure was a successful legal challenge on the basis that most citizens were excluded from the new lane.

Shoup extended the metaphor of the commons to considerations of appropriate charges for parking. Observing that free street parking is a form of commons, he suggests that pricing for parking should be structured such that it is free when parking-space occupancy is below 85%, because at that level drivers do not congest the street by cruising for parking. Under such conditions, "*it is then a public good in the sense that the marginal cost of adding another user is zero. But when demand increases, the public good becomes crowded, it takes time to find a vacant space, and the marginal cost of adding another user increases*."[55]

> Elinor Ostrom received a Nobel Prize for her work on commons governance that suggests some intriguing models. The central question is whether the users (and therefore beneficiaries) of the commons, if given time and space, could establish a governance model that would avoid the overuse described in Hardin's Tragedy of the Commons.[56] Ostrom established that it is possible to collectively establish usage, monitoring, and enforcement agreements and rules that result in a better net outcome than the costs and inefficiencies of state control, or the unequal distribution of benefits flowing from privatization.[57]
>
> According to a 2011 post by Jay Walljasper to a website called On the Commons, Ostrom offered the following eight principles for how commons can be governed sustainably and equitably in a community:

1. *Define clear group boundaries.*

2. *Match rules governing use of common goods to local needs and conditions.*

3. *Ensure that those affected by the rules can participate in modifying the rules.*

4. *Make sure the rule-making rights of community members are respected by outside authorities.*

5. *Develop a system, carried out by community members, for monitoring members' behavior.*

6. *Use graduated sanctions for rule violators.*

7. *Provide accessible, low-cost means for dispute resolution.*

8. *Build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system.*[58]

The literature review provided the project team with confidence that there are gaps in the knowledge that could be filled by the work of this project. The team moved forward to develop and expand a draft method.

III. THE DRAFT METHOD

The intent behind the Method developed in this research project is a repeatable process for calculating a 'build nothing and pay passengers' scenario for improving road transport outcomes using incentives paid to people who travel as passengers. Often, when considering what to do about a congested road facility, a range of options are considered, plus a 'do nothing' alternative. The options considered usually involve different configurations of facility expansion. In some cases, travel demand management (TDM) options are included, either alone or in combination, with facility expansion. These generally involve provision of public transport.

To the best of the project team's knowledge there have been no examples of options considered that sought to achieve the sort of capacity increase that facility expansion could provide through rewarding people for traveling as passengers, especially if this travel would be in private vehicles. However, it is noted that when the 'drive alone rate' is high, there is a large amount of seat-capacity unused in private vehicles. It would be ideal to have access to this capacity if it could just be unlocked. For example, 100,000 commuters could travel in 25,000 four-person carpools rather than 77,000 vehicles with an average occupancy of 1.3, reducing lane capacity requirements by two-thirds. And while the reference to 100% four-person carpools may be utopian, any increase in average occupancy that removes vehicles from the road provides a broad range of benefits: reduced vehicle miles travelled, reduced delay, and reduced emissions, to mention just a few examples.

The Method is designed to consider a corridor where there is traffic congestion and to calculate a) the present value of the future costs of paying incentives at a congestion clearing (or congestion managing) level, taking into account the current travel market and culture, the likely impact of induced and latent demand, and the likely growth in trip-making over time, b) the present value of the future benefits from applying such a solution, and c) the benefit-to-cost ratio that, if positive, would suggest the solution is worth consideration for the given location.

The project team does not propose that the results of any individual steps would be able to be generalized to other situations, but rather that the full method could be generalized. The team's expectation is that each step would be applied for each corridor that would be under consideration for CCPTP. Over time, with repeated application of the Method, the team envisages that rules of thumb might emerge. However, the Method would initially be developed and applied without trying to second guess whether the results of any individual step could be generalized.

Figure 3 and its descriptions of each step reflect the project team's thinking at the beginning of the project. The commentary that follows describes the steps and provides some adjustments to the original concepts that came from development of the case study documented in this report.

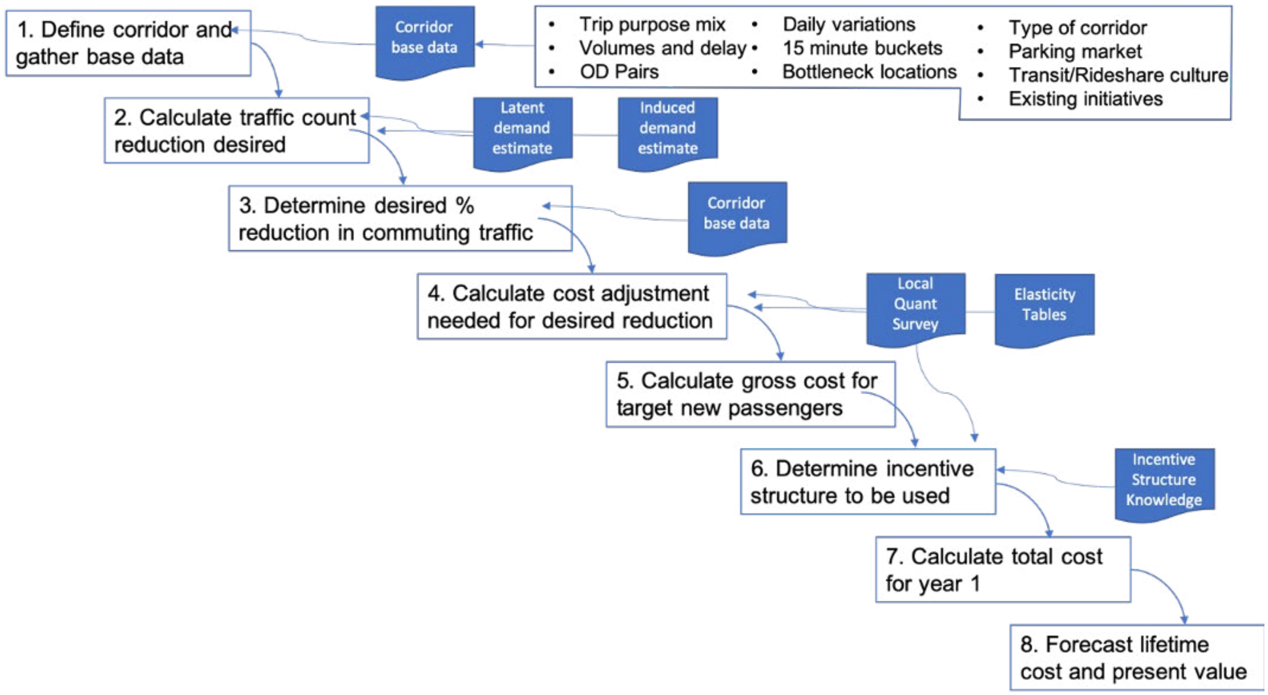


Figure 3. The Draft Method for Costs

Step 1: Define the corridor and gather base data

Clearly define the corridor(s) for incentive payment purposes. The working assumption is that the bottlenecks can be identified, and the source and destination of the traffic established in order to seek to reduce the traffic at each bottleneck. The ‘build something’ alternative might involve building several miles of road and expanding several interchanges. It might be useful to consider each interchange as a separate corridor for the purposes of the ‘build nothing’ alternative.

This first step is expected to be an iterative process.

The following are examples of base data that could be gathered:

1. Traffic flow data are often available, typically in 15-minute intervals for each lane, including class of vehicle (based on length) and the speed at an observation point. The observation point might not be at the bottleneck, so gather data from nearby observation points as appropriate. Because excess traffic is the result of arrivals at the bottleneck exceeding departures from the bottleneck, gather any information that gives insight into this imbalance. Any data that are available for smaller intervals of time (such as minute-by-minute) would be more useful.

   The focus should be on morning traffic flow data. While there is significant evening congestion, a main driver of evening congestion is the morning mode-choice by commuters. If people leave home in their own car, it is most likely that they will arrive home in their own car. By getting people to travel as passengers in the morning, they are highly likely to travel as passengers in the evening as well, so a morning-focused solution will improve the evening congestion as well.

2. Vehicle occupancy information for the vehicles in the congested traffic periods.

3. Vehicle trip purpose information for the vehicles in the congested traffic.

4. The presence and utilization of public transport vehicles along the corridor.

5. Origins and destinations of the vehicles in the congested traffic, in matched pairs if possible.

6. For each destination area:

   a. Parking pricing analysis: how many commuters park for free in employer-provided facilities; how many commuters pay to park in employer-provided facilities; how many park for free in public facilities or on-road; how many pay to park in public facilities or on-road.[59]

   b. Destination congestion statistics: how much local congestion is there at the destination, either from people circling to find a place to park, or because there are a lot of people who live at the destination using their cars to get to work or for very short trips.

   c. Existing programs at the destination for managing congestion, if any. For example, if there is a Transportation Management Association (TMA) for the destination, or if some employers are active in some way to reduce the amount of arriving SOVs, these approaches to mitigating congestion should be discovered, documented, and assessed for their potential to be integrated into the congestion clearing methodology.

   d. Any destination-related factors uncovered through focus groups with people from the corridor.

7. Existing programs that cover the corridor (not focused on individual destinations) for managing congestion, if any.

8. The presence of alternative routes and information about these routes, i.e. toll roads, or less direct routes between the same origins and destinations.

Step 2: Calculate the desired traffic-count reduction

Calculate the desired traffic-count reduction. It might be that this calculation should be carried out for a single location, or for several locations along the corridor. If congestion backs up from downstream, it will be important to understand the downstream situation.

Calculating the desired traffic-count reduction involves analysis and judgement. There are three main steps:

1. Ignoring induced and latent demand, how many excess vehicles are arriving at the bottleneck? How long is the queue that is forming? Does the queue form and then dissipate in a single smooth movement, or does it repeatedly ebb and flow? Create a model of the traffic arriving and departing the bottleneck on a minute-by-minute basis. Sum the excess on a 15-minute basis. Test to see whether all days have a similar shape, or if there is variability.

2. Consider latent demand. If the amount of excess identified in Step 1 could immediately be removed, then the peak-period traffic would flow smoothly. It is possible that the existing level of peak-period congestion is causing people who would like to travel at peak period to travel either before or after peak; to travel by an alternative mode (bus or train); or to travel by a different route.

3. Given the shape of the traffic flows, is it likely there is a significant amount of pre- and post-peak 'shoulder traffic' (traffic that is in the period immediately before and after the peak) that might move into an improved peak-period flow? If there is a lot of public transport use, is it likely that people will switch to driving if there is improved peak-period flow? Are there lots of people taking a less preferred route who would likely switch to the focus route if there is improved peak-period flow?

4. Use accumulated experience applied to the base data for the corridor to suggest how many vehicles would move into the peak period if the current excess were removed. This estimation is the latent demand adjustment. It could include commuters, commercial vehicles, and other trip purposes.

5. Consider suppressed demand. Would some people who are not traveling at all now start traveling on the target corridor if existing congestion were removed? Use accumulated experience to estimate a number of vehicles for induced demand.

The sum of excess current traffic, plus suppressed demand, is the number of vehicles that need to be removed to achieve and maintain free-flowing traffic today.

Step 3: Determine the desired percentage reduction in commuting traffic

The peak-period traffic is made up of commuters, freight and commercial vehicles, and people making a large variety of trips for different purposes, often one-off. The base data will help to provide some insights into this mix. Consider the mix as it is during peak, not the averages for the whole day.

1. Calculate the existing number of commuter vehicles during peak.

2. Divide the number of vehicles that need to be removed (step 2) by the existing number of commuter vehicles during peak—the answer is the percentage reduction required in total commuter vehicle flows.

Step 4: Determine the reward required to achieve the desired percentage reduction

Determine a 'reward curve' (see below) based on local survey results, and use the formula fit to the curve to estimate the amount of reward that would be needed to reduce the traffic by the desired percentage.

1. Carry out a local survey to understand the local market and the relative propensity to travel as a passenger at different levels of reward. This survey instrument is to be standardized as part of the Method, and it is hoped that as the Method is applied, the findings from an accumulation of surveys will help to clarify the implications of variations in survey findings. (Note that the survey might be a source of some of the data in Step 1).

2. Interpret the data from the survey to create a 'reward curve': a chart that shows the relationship between the size of reward and the proportion of commuters who will respond to the reward at each level.

3. Using appropriate levels of judgment, take the desired percentage reduction and apply it to the reward curve to find the value of reward required.

Step 5: Calculate the gross cost for the corridor for the volume of traffic to be removed

A relatively simple calculation comes next: the cost on a per passenger per day basis, multiplied by the number of vehicles that need to be removed. The result is not yet the total cost—it is necessary to adjust for people who are already traveling as passengers—but is the amount of value that will need to be delivered to get existing drivers to change.

Step 6: Determine the incentive-system structure that will be used

Four different components are anticipated for the incentive system:

1. An incentive related to getting started traveling as a passenger, perhaps a bonus for the first five successful trips, or for a single trip, or even for just registering;

2. An incentive related to reporting trip activity, so that in essence the data are being purchased. Such an incentive might be fixed on a per-trip basis;

3. An incentive related to how far the person travels as a passenger;

4. An incentive related to what time the trip is taken.

It is anticipated that there will be two main payment mechanisms that could be used for all four components above:

1. Cash, and/or

2. Lottery entries.

As mentioned in the literature review, people generally value a lottery entry at about double its actual value (determined as probability of winning times the amount of the prize), so a weighting of incentive mix towards lottery entries reduces the actual cost of the incentive while maintaining the perceived value.

For example, if there were to be a lottery component, and if all participants could convert as much of their money as they wanted into lottery entries, and if (say) all participants converted 50% of their money into lottery entries then the cost of providing $10 per day in value could be just $7.50 per day in reality (50% paid out = $5.00, and 50% converted to lottery entries that cost 50%, therefore = $2.50). The extent to which participants would be likely to convert their money into lottery entries could be tested in the survey suggested in Step 4.

Step 7: Calculate the total cost for year 1

Working with the expected average in the above calculation, work out how many people in total need to be paid at the calculated rate. It exceeds the number of vehicles that need to be reduced, because the incentive will also be paid out to people who are already traveling as passengers. There is likely no way to avoid paying existing passengers in addition to new passengers. However, if done carefully, paying any cost of them starting to travel as passengers can be avoided.

1. Multiply the total number of new passengers required times the year 1 cost per passenger

2. Multiply the total number of existing passengers times the year 2 cost per passenger (the year 1 cost less the cost of getting them started)

3. Sum these to arrive at the total incentive cost for year 1.

A couple of caveats for this calculation:

- It needs to be factored based on some assumption about the proportion of days of the year each person will travel as a passenger;

- It needs to allow for different levels of incentive required on different days of the week, month, or year—there is no need to pay for passengers on public holidays nor on lazy Mondays, or other days that less or no congestion is expected

Step 8a: Forecast the growth in demand on the facility and total costs over time and calculate the present value

1. Decide on the discount factor to use. Research the rate used by the local Department of Transportation so that estimations for this project can more easily be compared with estimations for other projects in the area.

2. Decide on the traffic growth factor to use and adjust for (probably) greater growth in the percentage of commuter traffic involved—i.e., any growth in commercial or goods vehicles will require an equal reduction in commuter vehicles.

3. Determine the rate at which the cost of the incentives will increase each year to maintain the target level of flow.

4. Determine number of years and calculate cost for each year.

5. Discount to the present.

Step 8b: Forecast the benefits from implementing the solution, and calculate the present value

1. Decide which benefits can be claimed for the solution: reduced delay, reduced fuel use and emissions, reduced VMT-related running costs, reduced accidents, reduced inconvenience due to congestion, increased opportunities, reduced stress, etc.

2. Estimate each stream of benefits for the first and subsequent years.

3. Discount to the present.

Step 8c: Calculate the net present value and benefit-to-cost ratio

1. Deduct the present value of the costs from the present value of the benefits to determine the net present value.

2. Divide the present value of the benefits by the present value of the costs to determine the benefit-to-cost ratio (BCR).

IV. PROJECT WORK

CALCULATIONS FOR ESTIMATING COSTS

Estimating excess traffic

Step 1 of the draft Method called for 15-minute data for the corridor, including traffic volumes through the peak period by class of vehicle, by origin and destination pairs, by trip purpose, and showing existing delay, daily variations of volumes, and average vehicle occupancy.

The goal is to calculate the current excess traffic, because as will soon be seen, the excess traffic is the amount of traffic that, if removed from the flow, would remove the queue that is referred to as 'the congestion.'

For the purpose of estimating excess traffic and delay, the team expected to be working with information that would be similar to that shown in Table 1 from a freeway in Massachusetts.[60] This same Massachusetts data source contains counts by different classes of traffic with the same degree of specificity, and the counts can be further broken down by individual lanes.

Table 1. Example of 15-minute Traffic Counts

Location ID	H8453_SB	Located On	INTERSTATE 93	Community	Stoneham
Counted By	TCDS_Combined	Between		County	Middlesex
Start Date	1/10/18	And		Module	
Start Time	12:00:00 AM	Direction	SB	Agency	MHD
		Source	TCDS_BIN_IMPORT_COMBINE	Owner ID	MhdHereAuto

	Speed Range (mph)															
Start Time	0-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86+	Total
4:15 AM	0	0	0	0	0	0	0	0	75	166	333	0	0	0	0	574
4:30 AM	0	0	0	0	0	0	94	0	0	202	471	0	0	0	0	767
4:45 AM	0	0	0	0	0	0	0	126	0	246	634	0	0	0	0	1006
5:00 AM	0	0	0	0	0	0	0	0	182	0	1307	0	0	0	0	1489
5:15 AM	0	0	0	0	0	0	0	0	303	999	682	0	0	0	0	1984
5:30 AM	0	0	0	0	0	0	0	0	315	1670	0	0	0	0	0	1985
5:45 AM	0	0	0	0	0	997	459	379	0	0	0	0	0	0	0	1835
6:00 AM	0	0	0	0	0	0	995	915	0	0	0	0	0	0	0	1910
6:15 AM	0	0	0	0	1345	0	356	0	0	0	0	0	0	0	0	1701
6:30 AM	0	0	438	865	0	0	419	0	0	0	0	0	0	0	0	1722
6:45 AM	743	389	0	372	0	0	0	0	0	0	0	0	0	0	0	1504
7:00 AM	1109	0	339	0	0	0	0	0	0	0	0	0	0	0	0	1448
7:15 AM	1010	306	0	0	0	0	0	0	0	0	0	0	0	0	0	1316
7:30 AM	974	0	350	0	0	0	0	0	0	0	0	0	0	0	0	1324
7:45 AM	978	0	331	0	0	0	0	0	0	0	0	0	0	0	0	1309
8:00 AM	997	0	317	0	0	0	0	0	0	0	0	0	0	0	0	1314
8:15 AM	961	0	0	345	0	0	0	0	0	0	0	0	0	0	0	1306
8:30 AM	916	0	0	346	0	0	0	0	0	0	0	0	0	0	0	1262
8:45 AM	0	0	0	0	0	254	845	0	0	0	0	0	0	0	0	1099
9:00 AM	0	0	0	0	0	0	0	181	0	0	617	295	0	0	0	1093
9:15 AM	0	0	0	0	0	0	186	0	0	0	657	357	0	0	0	1200
9:30 AM	0	0	0	0	0	0	0	213	0	0	1109	0	0	0	0	1322
9:45 AM	0	0	0	0	0	0	0	202	0	0	700	383	0	0	0	1285
10:00 AM	0	0	0	0	0	0	0	0	199	359	768	0	0	0	0	1326

The purpose of obtaining the count data was to determine the amount of excess traffic. It turns out that the information in Table 1 is not sufficient to estimate excess traffic. It only shows the traffic that passed through the bottleneck, not the amount of traffic backed up waiting to get through at any point in time. It also does not tell us if this location is actually a bottleneck–it is possible that the congestion at this location is caused by traffic backing up from a downstream bottleneck.

Vickrey had provided an example that included a known quantity of excess traffic, as shown in Table 2.[61]

Table 2. Factors Describing Vickrey's Bottleneck

Factor	Value
Traffic flow after peak (vehicles per hour)	2,800
Traffic flow during peak (vehicles per hour)	4,400
Bottleneck capacity (vehicles per hour)	4,000
Duration of peak traffic flow (minutes)	90
Excess traffic (vehicles) = (Traffic flow during peak – Bottleneck capacity) / (Duration of peak flow)	600
Queue duration (minutes) = (Duration of peak flow) + (Excess traffic) / (Bottleneck capacity – Traffic flow after peak)	120
Maximum delay to any one vehicle (minutes) = (Excess traffic) / (Bottleneck capacity)	9
Total vehicles experiencing some delay (vehicles) = (Duration of queue) × (Bottleneck capacity)	8,000
Total delay (vehicle minutes) = 0.5 × (Queue duration) × (Excess traffic)	36,000
Average delay per vehicle delayed (minutes) = Total delay / Total vehicles experiencing delay	4.5

Vickrey's queue can be represented as shown in Figure 4. The queue grows at the rate of 6.67 vehicles per minute (while the traffic arriving at the bottleneck exceeds the rate at which it departs) and shrinks at the rate of 20 vehicles per minute (once the traffic departing the bottleneck exceeds the rate at which traffic is arriving). The total amount of vehicle delay is the area under the line as each vehicle in the queue for each minute accumulates a vehicle-minute of delay.

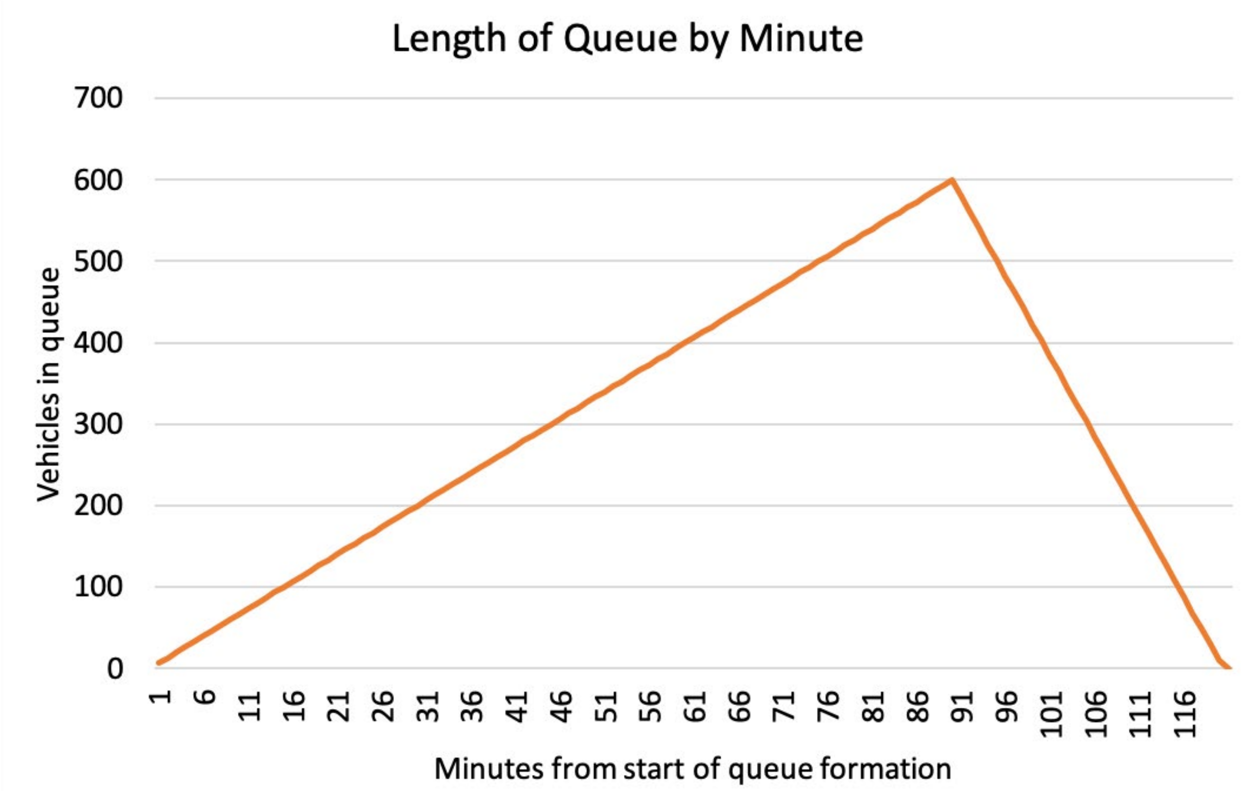


Figure 4. Length of Queue by Minute: Vickrey's Bottleneck

In contrast, the information in Table 1 (from Massachusetts) shows traffic queued-up from 6:45 am to 8:30 am, but it is not possible to derive from Table 1 the length of the queue backed up behind it. Vickrey's use of the length of the queue to indicate excess traffic suggests it is an important factor. In Vickrey's example, queue length equals excess traffic.

It became evident that the length of the queue was not the whole story. Firstly, it is difficult to know (for a real situation) the simplified set of facts that Vickrey uses in his example. Secondly, except in unusual circumstances, the rate of traffic arriving at a queue is unlikely to be as uniform as Vickrey's example would suggest. It is known that queues ebb and flow. Suppose, for example, that instead of a single stream of peak traffic, Vickrey's traffic was divided into two peaks, with an initial queue forming, dissipating, and a second queue forming and dissipating, both queues 600 vehicles deep at their maximum, as shown in Figure 5. In this modified case, vehicles arrive at the rate of 5,200 vehicles per hour for 30 minutes, 2,800 vehicles per hour for 30 minutes, and 5,200 per hour for the final 30 minutes. (Note that the total traffic in 90 minutes is the same as Vickrey's initial example: 6,600 vehicles.) To remove both queues, 600 people would need to be convinced to leave the early peak flow, and 600 to leave the late peak flow, in order to remove the queue all together. The excess traffic in this case is therefore 1,200 vehicles, while total delay is the same as in the base case.

The challenge for the project team was to determine a formula for calculating the excess traffic in an environment where the queue length varied constantly, perhaps as shown in Figure 6, a hypothetical example to illustrate an important point. The team's conclusion is that excess traffic is determined by the difference between the rate at which vehicles arrive at the bottleneck (or the back of the queue) and the rate at which vehicles leave the front of the queue and is the sum of these differences for each minute that the arriving rate exceeds the departing rate.

Any time the queue grows, the arriving vehicles comprise part of the total excess traffic. Vehicles arriving while the queue is shrinking do not form part of the excess traffic (even though they wait in the queue). In the modified Vickrey example above, there are two 30-minute periods during which the arriving traffic rate exceeds the departing traffic rate by 20 vehicles per minute, so the excess traffic is (30 × 20) + (30 × 20) = 1,200.

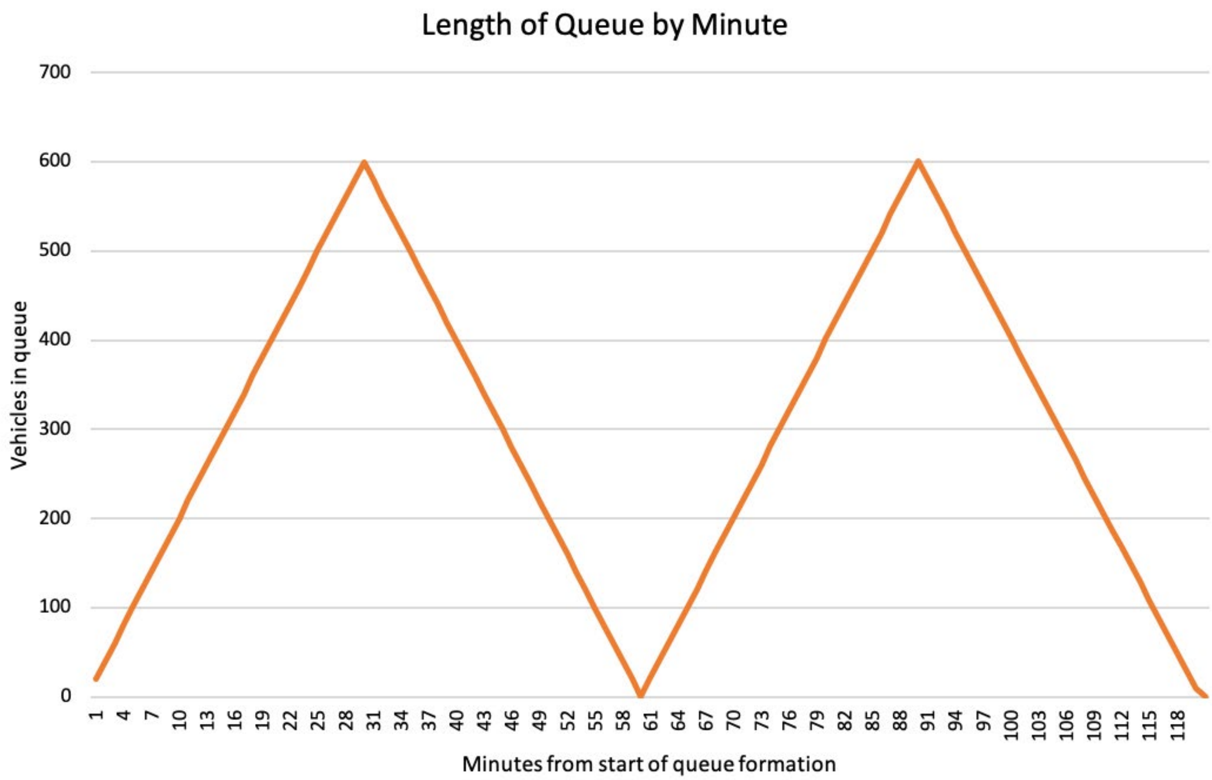


Figure 5. A Two-Peak Queue Example

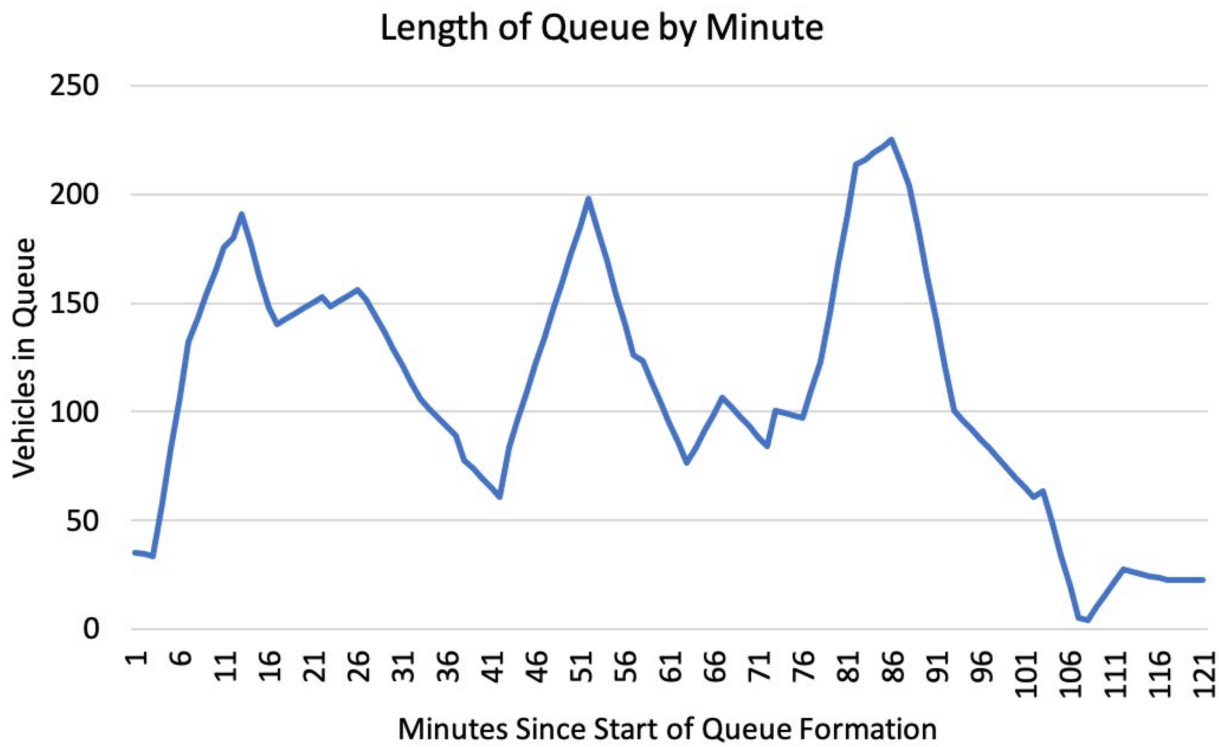


Figure 6. Example of Queue with Fluctuating Length

In the example in Figure 6, there are 49 one-minute periods during which the queue grows, and the excess traffic is calculated as 550 vehicles, even though the maximum queue length is less than 250 vehicles, and there are three distinct 'peaks' in the queue.

To derive similar information for a real situation, it is desirable to have data about the rate at which vehicles arrive at the bottleneck or the back of the queue, on a minute-by-minute basis, as well as the rate at which the vehicles depart. Alternatively, if there is an available measure of the actual queue length minute-by-minute, and if the departure rate is known, the net of arrivals and departures could be calculated.

In the event that something temporarily constrains the rate of departure from the queue, the queue could be growing even with a low rate of vehicles arriving. Hence, the minute-by-minute rate of vehicles departing the queue should also be taken into consideration.

Optimal data sources would be minute-by-minute traffic counts from locations beyond the longest likely length of the queue on each road leading to the bottleneck, plus minute-by-minute traffic counts of vehicles leaving the bottleneck. Ideally, data would be accumulated over some period of time so that averages could be used for each day, recognizing that there will most likely always be variations. The goal is to arrive at an assessment of the daily excess traffic, so that an initial price can be set for removing this excess.

An alternative data source would be to survey a random sample of people who drive to the bottleneck during the peak period, asking what time they typically arrive at the bottleneck (or perhaps, what time they leave home, and making an adjustment for the time it takes to get to the bottleneck). Taking this information, together with an assumption about the rate of departure from the bottleneck, a minute-by-minute queue could be modeled and compared with any other available flow data for validation.

By whichever method, a chart could be generated that would show the traffic arriving at the bottleneck minute-by-minute, as shown in Figure 7.

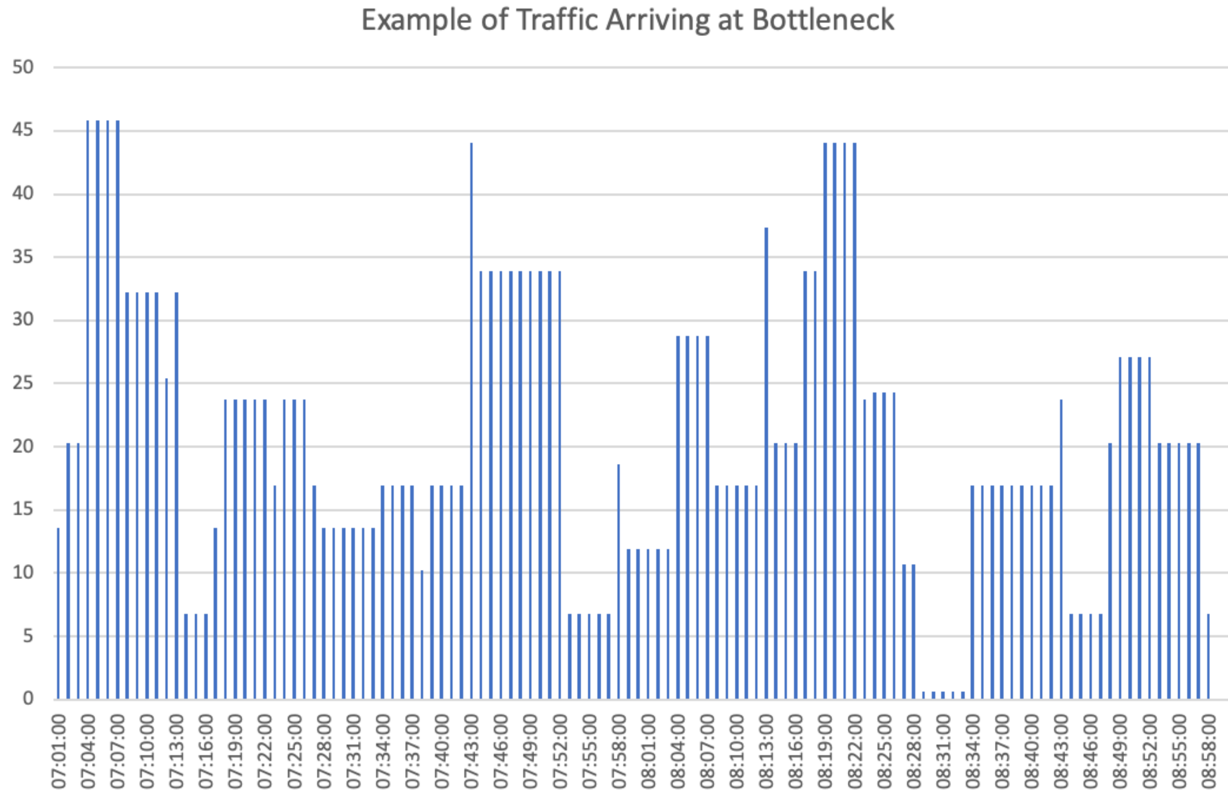


Figure 7. Vehicles Arriving at the Bottleneck by Minute

Taking into account the available departure capacity, arriving traffic could be classified into ‘within bottleneck capacity’ and ‘excess traffic’ as shown in Figure 8. The top of the blue columns represents the capacity of the bottleneck (the rate at which traffic can depart), and the red portions of the columns represent excess traffic.

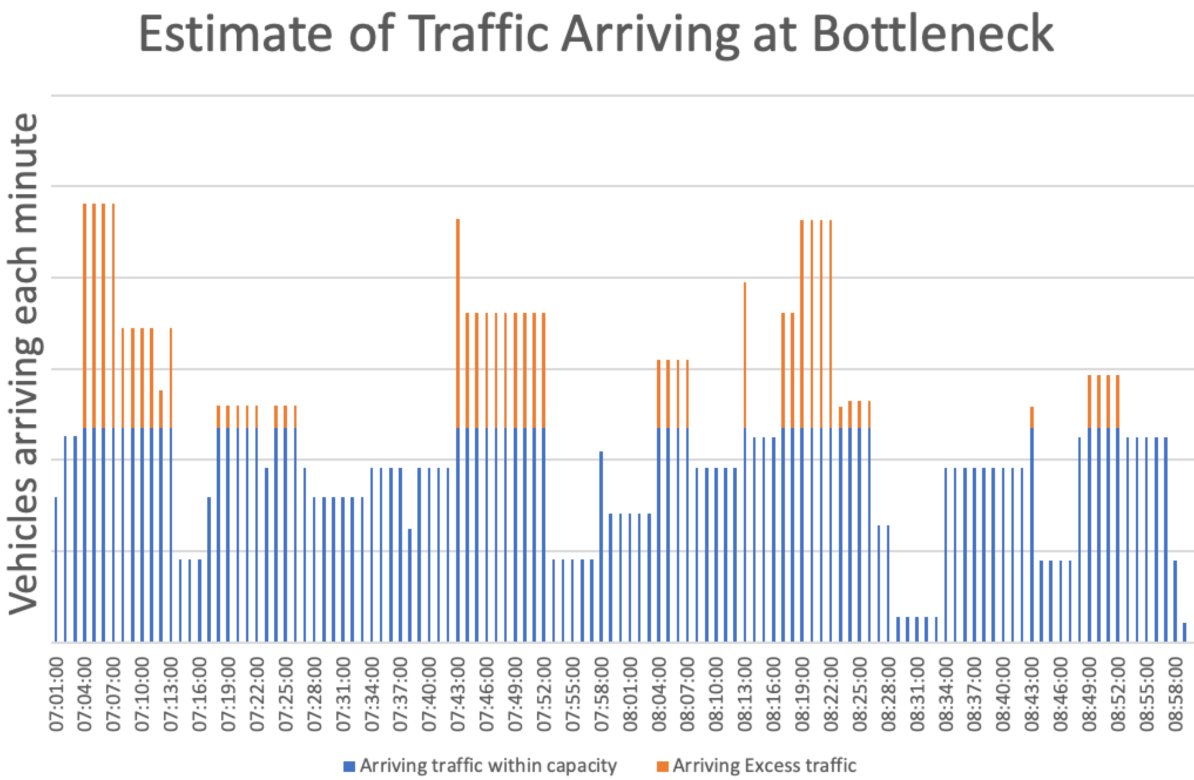


Figure 8. Arriving Traffic Analyzed into 'Within Capacity' and 'Excess' (by minute)

Relating a single bottleneck to a corridor full of congested traffic

Step 1 of the Method called for definition of the corridor and possible analysis of a corridor as a sequence of individual bottlenecks. The discussion above talks about a single bottleneck. It makes an unstated assumption that congestion is caused by bottlenecks, and that these will be at static locations.

Slow-moving traffic can be caused by three major mechanisms. These mechanisms are bottlenecks, accidents, and random braking.

- A bottleneck is any location where the capacity of the road reduces compared with the capacity of the immediately upstream section. This can be caused by the classic situation of a reduction in the number of lanes, such as a narrowing of the road or the joining of an on-ramp. It can also be caused by the nature of the section of road such as curves, rises, camber, visibility, or distraction that results in the throughput of traffic of the downstream section being lower than the throughput of the traffic from the upstream section. The bottleneck causes slow-moving traffic when the volume of traffic arriving at the bottleneck exceeds the amount of traffic that can get through the bottleneck.

- Accidents cause slow-moving traffic by constricting one or more lanes, or by distracting drivers who like to look at the accident as they drive by. In essence an accident creates a temporary bottleneck. Greater levels of traffic result in greater numbers of accidents.

- Traffic moving freely on a section of road, where there is no variability in the capacity of the road, can also be slowed down by drivers touching their brakes, causing drivers behind them to touch their brakes, and so on in such a way that a 'phantom' bottleneck is created.

This project focuses on recurrent traffic congestion that is caused by bottlenecks. Stated another way, it is focused on situations where the amount of arriving traffic repeatedly exceeds the capacity of the down-stream section of road.

In the situation where there is a corridor, usually comprised of a length of road (or possibly parallel roads) with intersections or interchanges, and parts of the corridor have recurrent congestion, part of the challenge for determining the amount of excess traffic will be deciding where the bottlenecks are and whether the slow-moving traffic at one location such as an interchange is caused by the bottleneck at that location, or if it is caused by traffic backing up from a downstream location. For example, a highway that runs in to a central business district (CBD) might back up from the CBD off-ramp all the way back to and beyond an interchange a mile from the CBD, and further to an interchange two miles from the CBD. The analysis of excess traffic would need to consider the rate of traffic departing the CBD off-ramp as the major bottleneck before analyzing the traffic at the one- and two-mile interchange on-ramps. Reduction of traffic arriving at the CBD off-ramp would likely include reductions to traffic that joins at the upstream interchanges. This would be more complicated still if (for example) there were another interchange at three-miles upstream that the backed-up queue from the CBD off-ramp did not reach, that had its own localized congestion, and whether a reduction at the CBD off-ramp would resolve that localized congestion or not.

Estimating suppressed demand, induced demand, and intra-peak demand shift

The draft Method (Figure 3) called for estimates of the amount of new traffic that would be generated as a result of removing congestion, assuming the incentive program succeeded in removing congestion. Unfortunately, the terminology surrounding this part of the topic is somewhat confusing.

The literature and the focus groups confirmed that where there is a bottleneck causing congestion, people adjust to the congestion. As discussed in the previous section, survey questions about current travel, and how respondents' trip-making would change if congestion went away, can reveal the amount that people would change their time or mode of travel; their frequency of travel (if they do not already travel every day); and the amount they would start to travel (if they do not travel at the moment).

Intra-peak demand shift is the term coined by the project team to refer to the shift of trip times within the peak period.

Referring back to Vickrey's example, imagine that the preferred trip times of the people passing Vickrey's bottleneck, for all traffic, were actually in the last hour of the current 90-minute peak demand period. Imagine that no one wanted to travel during the first half hour, but over time, because of the bottleneck, the traffic had spread itself out so that 6,600 vehicles arrived over the 90-minute peak, or 2,200 for each of three 30-minute periods. Vickrey's suggestion was that removing the excess of 600 through whatever means would remove the constraint on the remaining traffic (the queue). However, suppose people in the remaining traffic of 6,000 vehicles decided that, with the reduction in the queue, there is capacity for them to travel closer to their preferred time. Imagine that as a result of the reduction of 600 vehicles, 2,000 vehicles currently arriving in the first half-hour peak demand period shifted their departure time and tried to arrive during the second and third half-hour periods. This shift would be an 'intra-peak demand shift,' and while Vickrey's queue would have initially been removed by incentivizing 600 people to change their trips, the queue would now re-form, starting a little later but potentially being larger and lasting longer than the removed queue.

Suppressed demand is people not making trips or making fewer trips than they otherwise would or making trips by a less preferred route or mode (all of which can be found out via survey). Removal of the congestion will release those trips, which will show up as additional trips during the peak period.

Induced demand is the expansion of trips caused by expanding economic activity. For example, if the general population grows, it is expected that there will be an increase in the number of people who wish to commute.

The new addition to the picture is the intra-peak demand shift. The intra-peak demand shift is especially important for CCPTP, because the removal of initial excess will create space that other existing traffic could move into, causing the queue to re-form. In order to maintain the reduced length of queue, an additional incentive will be required to reward enough additional passengers to absorb this shift, or to convince passengers to continue traveling at their less preferred time.

Using an assumption of removed congestion, it is possible to estimate the amount of intra-peak demand shift, new trips from suppressed traffic, and new trips from induced traffic to predict the future demand situation for each 15-minute period (or minute-by-minute) through the peak. For each period, the quantity of excess traffic, and therefore the number of people whom the solution needs to convince to travel as passengers, can be determined.

By dividing the desired number of passengers by the total commuter traffic for each time period, the required percent reduction of commuter traffic can be calculated.

Calculating the value of incentives required to reduce the traffic

Reward curves

The Comsis Report had created tables that predicted the impact on traffic volumes of different combinations of incentives and SOV charges.[62] These had been updated for inflation and slightly changed by VTPI in 2000.[63] The project team further updated the tables for inflation to August 2019, now shown in Figure 9. In these tables, the terms 'rideshare oriented,' 'mode neutral,' and 'transit oriented' refer to the level of rideshare (in this case carpool and vanpool) compared to the level of transit use in a corridor. If the former is greater, the route is characterized as 'rideshare oriented.' If the latter is greater, the route is characterized as 'transit oriented.' If the amount of rideshare and transit is about equal, the route is characterized as 'mode neutral.'

Table 1	Rideshare/Transit Subsidy = $0				
Worksite Setting	**Daily Parking Charge (Aug 2019 U.S)**				
	$0.00	$1.98	$3.95	$6.08	$7.90
Low density suburb, rideshare oriented	0	5.9	13.1	21	28.6
Low density suburb, mode neutral	0	6.5	15.1	25.3	36.1
Low density suburb, transit oriented	0	6.7	15.7	26.7	38.8
Activity center, rideshare oriented	0	10.8	21.4	30.7	37.9
Activity center, mode neutral	0	12.3	25.1	37	46.8
Activity center, transit oriented	0	14.3	30.5	46.8	61.4
Regional CBD/Corridor, rideshare oriented	0	12.4	21.7	28.2	32.5
Regional CBD/Corridor, mode neutral	0	17.5	31.8	42.6	50
Regional CBD/Corridor, transit oriented	0	22.5	42.6	58.7	70.6
Values in the table indicate the percentage reduction in commute trips compared with no fees or subsidies.					

Table 2	Rideshare/Transit Subsidy = $1.98				
Worksite Setting	**Daily Parking Charge (Aug 2019 U.S)**				
	$0.00	$1.98	$3.95	$6.08	$7.90
Low density suburb, rideshare oriented	5.8	13	20.9	28.5	35
Low density suburb, mode neutral	5.6	13.9	23.8	34.4	44.5
Low density suburb, transit oriented	5.5	14.1	24.8	36.6	48.3
Activity center, rideshare oriented	10.2	20.8	30	37.2	42.4
Activity center, mode neutral	10.5	23.1	34.9	44.8	52.2
Activity center, transit oriented	11.3	27.2	43.6	58.6	70.9
Regional CBD/Corridor, rideshare oriented	11.3	20.6	27.2	31.6	34.4
Regional CBD/Corridor, mode neutral	14.5	29.1	40	47.7	52.8
Regional CBD/Corridor, transit oriented	18.1	38.8	55.6	68.2	76.9
Values in the table indicate the percentage reduction in commute trips compared with no fees or subsidies.					

Table 3	Rideshare/Transit Subsidy = $3.95				
Worksite Setting	**Daily Parking Charge (Aug 2019 U.S)**				
	$0.00	$1.98	$3.95	$6.08	$7.90
Low density suburb, rideshare oriented	13	20.8	28.4	34.9	40
Low density suburb, mode neutral	12.7	22.4	32.8	42.9	51.5
Low density suburb, transit oriented	12.6	22.9	34.5	46.1	56.5
Activity center, rideshare oriented	20.1	29.3	36.6	41.8	45.4
Activity center, mode neutral	21.2	33	42.9	50.4	55.8
Activity center, transit oriented	24	40.5	55.8	68.6	78.3
Regional CBD/Corridor, rideshare oriented	19.6	26.2	30.6	33.5	35.3
Regional CBD/Corridor, mode neutral	26.3	37.5	45.4	50.7	54.1
Regional CBD/Corridor, transit oriented	34.8	52.3	65.6	74.9	81.1
Values in the table indicate the percentage reduction in commute trips compared with no fees or subsidies.					

Table 4	Rideshare/Transit Subsidy = $6.08				
Worksite Setting	**Daily Parking Charge (Aug 2019 U.S)**				
	$0.00	$1.98	$3.95	$6.08	$7.90
Low density suburb, rideshare oriented	20.7	28.3	34.8	39.9	43.5
Low density suburb, mode neutral	21	31.3	41.3	49.9	56.6
Low density suburb, transit oriented	21.1	32.5	44	54.5	62.8
Activity center, rideshare oriented	28.7	36	41.2	44.8	47.2
Activity center, mode neutral	31.1	41	48.7	54.1	57.7
Activity center, transit oriented	37.3	52.9	66.3	76.5	83.8
Regional CBD/Corridor, rideshare oriented	25.3	29.8	32.8	34.4	35.6
Regional CBD/Corridor, mode neutral	35	43.1	48.5	52	54.3
Regional CBD/Corridor, transit oriented	48.9	62.9	72.8	79.5	83.8
Values in the table indicate the percentage reduction in commute trips compared with no fees or subsidies.					

Table 5	Rideshare/Transit Subsidy = $7.90				
Worksite Setting	**Daily Parking Charge (Aug 2019 U.S)**				
	$0.00	$1.98	$3.95	$6.08	$7.90
Low density suburb, rideshare oriented	28.2	34.7	39.8	43.4	45.8
Low density suburb, mode neutral	29.9	39.8	48.4	55.2	60
Low density suburb, transit oriented	30.5	42	52.5	61	67.4
Activity center, rideshare oriented	35.4	40.7	44.3	46.6	48.1
Activity center, mode neutral	39.3	47	52.5	56.2	58.6
Activity center, transit oriented	50	63.8	74.6	82.4	87.7
Regional CBD/Corridor, rideshare oriented	29	31.8	33.7	34.8	35.5
Regional CBD/Corridor, mode neutral	40.9	46.4	50	52.3	53.7
Regional CBD/Corridor, transit oriented	60	70.5	77.7	82.3	85.3
Values in the table indicate the percentage reduction in commute trips compared with no fees or subsidies.					

Figure 9. Comsis Reward Tables (updated to 2019)

It can be seen that a rideshare/transit subsidy and a parking charge work in the same direction: a driver who becomes a passenger avoids paying for parking and receives an incentive. The combination delivers both a carrot and a stick. It can be seen from the tables in Figure 9 that the combination of parking and incentives gives slightly more credit to the stick than to the carrot: Column 2 of Table 1 shows $0 incentive and a $1.98 parking charge, while Column 1 of Table 1 shows $1.98 incentive and $0 parking charge, and the impact of the former is slightly greater all the way down the column than the impact of the latter (for example, Table 1, Column 2, Row 1 shows 5.9% traffic reduction while Table 1, Column 1, Row 1 shows 5.8% traffic reduction). The Comsis report makes the point that incentives are easier to implement but create a problem for funders, while parking charges can provide a source of revenue to fund the incentives.

In Figure 10, the Comsis tables have been converted for this report on the assumption of zero parking charges, and different levels of incentive, for one example type of corridor (regional CBD/Corridor, mode neutral). Similar charts can be calculated for different configurations. The Figure 10 chart can be used to predict the amount of incentive required to achieve any target level of commuter traffic reduction.

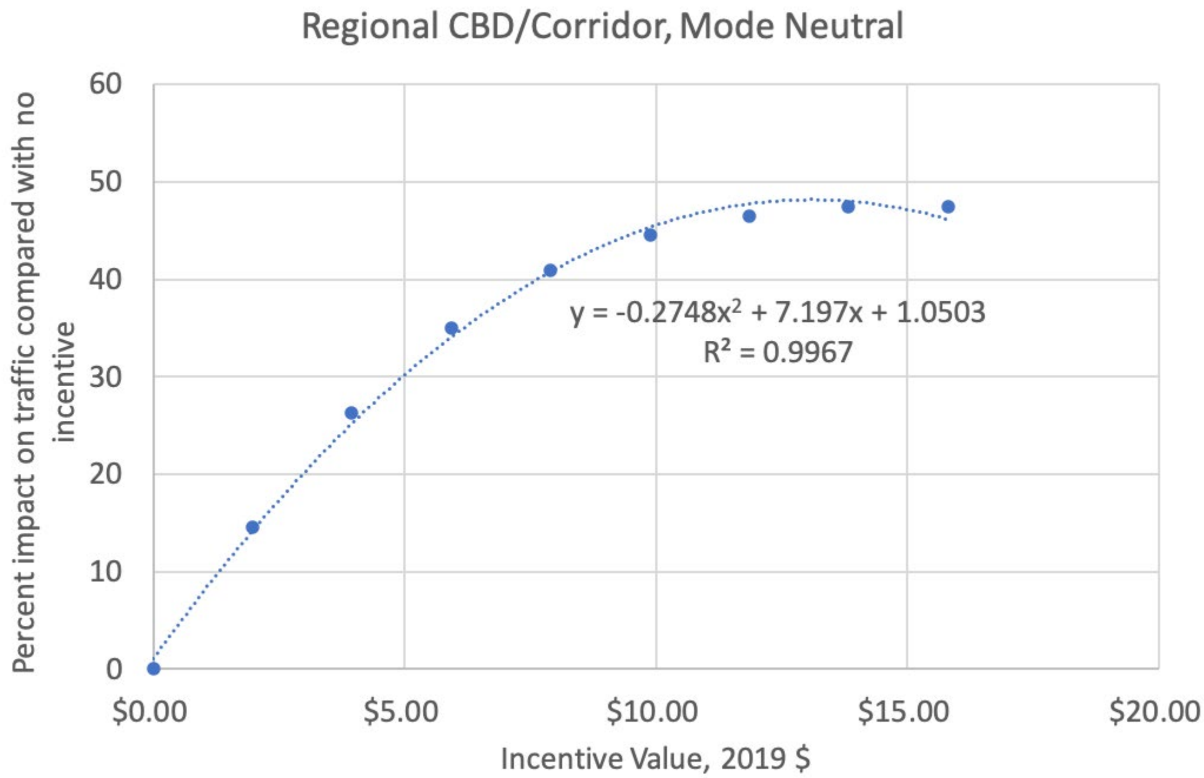


Figure 10. Comsis Calculated for One Corridor, Incentive Only (2019 dollars)

The challenge for the project team was to find a method of creating a corridor-specific chart that could be used in the same way as envisaged for Figure 10. The original tables were derived from work in the early 1990s or earlier, and the project team was unable to locate any reports of further work that would have validated these tables in the intervening years.

The method chosen to meet the challenge was a series of questions in a representative survey of people who do and who might use the corridor, asking the following:

a) Are you the sort of person who would travel as a passenger (by bus, carpool, vanpool) if it were easy to do?

b) If no, would it change your answer if a program were in place to pay an incentive to people who travel as passengers during the times when there is traffic congestion?

c) If yes to (a) or (b), imagine a fund of money is available (say from a federal program) to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so—and perhaps it saves time—how much would you need to be paid to switch from being a driver to be a passenger?

The answers to these questions would provide realistic data that could be used to derive a reward curve similar to the one shown in Figure 10. Only people who indicate their real interest in traveling as passengers would contribute a price. As long as the survey was representative of the people who do or might use the corridor in question, the proportion of the sample giving any particular price could be assumed to be the proportion of the total population of travelers who would respond to that price—as long as the caveat is met that *"it* *is easy to do, and it adds no extra time (perhaps it saves time).*"

The reward curve derived through such a survey would be relevant only to the corridor from which it was gathered. Further, the reliability of the reward curve would depend on a number of issues including:

1. How people interpreted the question while doing the survey;

2. How carefully people thought about their answers while doing the survey;

3. What people took into account (that the researchers could not be aware of) while answering the questions.

Significant value will come from using the survey in a corridor, and then running a pilot project to see whether the response to any given price is consistent with the findings of the survey.

The project team was able to construct a reward curve for the case study corridor that bore significant resemblance to the one created from Comsis shown in Figure 10.

Segmentation

As well as a reward curve, the responses to the survey questions above would deliver the proportions that different sorts of people represent in the commute mix in the corridor: people who will only drive alone; people who will only drive but will take passengers (for money or not); and people who are prepared to travel as a passenger (for money or not). These groups could be referred to as segments. In the future, knowing more about how each of these segments responds to different messages or interventions could be the key to effective management of vehicle trip demand through use of incentives.

Winters et al had researched commuter segmentation, and the project team explored the idea that the questions from that study, which assigned every respondent to a segment, would be a useful complement to the survey for this project.[64] The team thought that perhaps these previously determined segments could be used in future projects as a shortcut for calculating the reward curve.

The proportions of people in each of Winters' segments had contributed to the project team's expectation that there would be sufficient people willing to travel as passengers, given sufficient reward. In the locations sampled by Winters et al., 20% of travelers, or fewer, were 'car lovers/devoted drivers' who would be unlikely to participate as either a driver or passenger in a passenger-focused solution—leaving 80% who might be positively disposed to a passenger solution. There was a sense that 80% would be sufficient for passenger-based congestion-resolving solutions to work. This expectation came back later in a surprising way.

The problem with integrating with the Winters et al. work is that to derive the segments of the respondents would require adding 16 or 17 questions to the survey, potentially increasing survey fatigue and dropping response rates. Efforts to create a shortened list of questions, targeting a maximum of three so that the additional questions would have minimal impact on survey completion, were unsuccessful. It was decided that use of this segmentation methodology would not provide sufficient additional value for the potential survey fatigue impact. It might still be beneficial to link to a useful segmentation methodology, but this linkage was not made for the case study.

Applying the reward curves to the desired volumes of traffic reduction

Since the project team had not found any evidence of the Comsis tables being used to drive actual congestion reduction, there was no described method for their use. Initially it was envisaged that the volume of reduction required would be applied to the formula for the reward curve on an appropriate basis (every 15 minutes, every half hour, every hour, etc.) as appropriate to the analysis. The team anticipated that there would be periods when a greater proportion of people would be required to switch to being passengers due to intra-peak demand shift, and that therefore the reward curve would be applied differently each period.

An important concern would be what would happen if the modeling found, due to intra-peak demand shift, that either a) the physical capacity of the corridor in a time period was unable to handle the number of ‘drive only, alone’ and ‘drive only, with passengers’ vehicles in the time period; or b) the percentage reduction required for a time period exceeded the range of pricing on the reward curve. A mechanism would be required to encourage some portion of the travelers (passengers and drivers) to travel at a different time, either before or after the peak demand period.

It was realized at this point that the Comsis tables were not designed for removal of congestion but rather for a percentage reduction in the amount of commuter travel that might lead to a reduction in congestion. Comsis did not anticipate or address intra-peak demand shift.

The conclusion of the project team was that the reward curve would deliver the cost to shift the appropriate number of people to being passengers. A separate reward concept would be required to convince them to travel as passengers at less preferred times.

Judgment and available data should be used to estimate the value required each day of the week and to convert to an annual value. While many transportation projects use anywhere from 260 to 365 days per year for their calculations of benefits, for CCPTP the total should be adjusted to a reasonable estimate of the actual number of days incentives might be paid: 260 week days per year, less school holiday days and national and local long weekends.

CALCULATIONS FOR ESTIMATING BENEFITS

Estimating the benefits of removing congestion

Reduced cost of vehicle delay

The cost of congestion is typically calculated as the amount of vehicle delay multiplied by an appropriate hourly rate for the people in the delayed vehicles.

The above discussion about excess traffic shows that the area under the line on a minute-by-minute graph of the traffic queue is the quantity of vehicle-minutes of delay for the period in question. A model of traffic arriving and departing the queue by minute can provide an estimate of total delay by summing the length of the ending queue each minute. The cost of delay can then be determined by multiplying the appropriate cost by the total vehicle hours of delay.

Reduced cost of excess emissions

An additional congestion cost is the environmental cost of emissions from slow-running traffic sitting in the queue, that is, the amount of carbon dioxide equivalent (CO_2-e) produced by vehicles while they are in the queue. (CO_2-e combines all the greenhouse gases included in vehicle emissions, including nitrogen oxides, carbon monoxide, and methane, stated in a single equivalence to carbon dioxide given the greenhouse effect of each different gas.)[65] There are confounding factors that make the amount of CO_2-e difficult to estimate. Each vehicle will have a different rate of emissions, depending on the size of the engine, the fuel type, and the tuning of the engine. Electric vehicles will have no emissions. Vehicles that shut off rather than idling will also expel fewer emissions—modified perhaps by the need to restart to keep moving forward in the queue.

The amount of CO_2-e is derived from the literature as a combination of the rate of fuel consumption per hour while idling (liters per hour), and the rate of emissions of CO_2-e in kg per liter.[66] These are multiplied by the total delay.

Reduced cost of traveling at a less-preferred time, or not at all

As will be discussed elsewhere, where a bottleneck exists, people adjust their travel to deal with the bottleneck. This adjustment was confirmed by the focus groups and the survey. People travel earlier either to avoid the congestion or to allow for the delay. People travel later to avoid the congestion. Only a small proportion of people travel at whatever time they are ready and take the congestion as it comes. In addition, some people opt not to travel, working from or near home rather than seeking employment further afield.

Information about how people adjust to deal with the bottleneck can only realistically be obtained via survey. There are four questions that can be asked: how much impact does the congestion have; what do you do as a result; what time do you leave home at the moment (if at all); and what time would you leave home if the congestion went away?

The answers to these questions expose an ‘inconvenience factor’ that is caused by the congestion. It is a real cost that is borne in greater levels of stress, reduced family time, reduced sleeping time, and reduced productivity at work, to mention a few examples. It can be quantified by taking the difference between departure times with congestion and without congestion from the survey.

This benefit is not typically calculated for transportation project analysis, so there is no accepted method nor rate for its calculation. The project team suggests using the same hourly rate as that used to value delay.

Reduced cost of suppressed economy

Further, congestion potentially imposes a cost on the local economy. This cost is equivalent to the net increase in economic activity that might occur if the congestion were removed. In one report, for Auckland, New Zealand, a net economic uplift of 3% was forecast as a result of removing traffic congestion.[67] The calculation of this benefit is also not usually carried out for transportation projects, so there is no accepted method nor rate for its calculation. The project team did not include this benefit in the benefit cost analysis.

Estimating other benefits

Reduced vehicle miles travelled

With CCPTP, a significant proportion of commuters will switch to traveling as passengers, therefore reducing the miles their own vehicles will travel. Reduced driving will result in reductions in parking costs at the destination, as well as reduction in vehicle costs such as repairs and maintenance, fuel consumption, and depreciation. These are benefits that are usually calculated for transportation projects. Average round trip distances should be calculated, and assumptions made for average rates for each avoided cost type.

Improved road safety

Crashes are predicted on a per-VMT basis, and the reduction of VMT should therefore lead to a reduction in crashes and their attendant costs. This benefit is usually calculated for transportation projects and should be included here. Rates are available from a number of different sources.[68]

FOCUS GROUPS

Having carried out a comprehensive search of the literature, the research team used focus groups to help think about the issues a payments-to-passengers program might encounter. From the literature there were some specific matters that needed to be explored, including the extent to which people leave earlier or later to avoid congestion, and the existence and rates of charges for parking at the destination.

The project team lead three focus groups in San Jose, California, during March 2019. The focus groups were structured to: allow participants to discuss their personal experiences with commuting in traffic; elicit from the participants their ideas for improving the transport system; and then to steer the conversation toward a discussion of carpooling. Having arrived at a discussion of carpooling, participants were asked to provide suggestions for designing a carpool incentive program. Once the group had collectively designed this program, participants were asked whether such a program would influence them to begin carpooling, and if not, why not.

The main findings from the focus groups were that while there is interest in carpooling, there are concerns about the challenges of finding suitable partners, and the safety implications of carpooling with people who are not known to them, as might be the case if carpools were arranged through smart-phone apps. Several participants expressed tentative willingness to carpool on an occasional basis, e.g., one or two days a week. Some would like to be able to carpool one-way, e.g., ridesharing in the morning but not back in the evening. Third-party provision of carpool vehicles was proposed as an attractive strategy, as it would enable drivers as well as passengers to avoid both operating costs and liability issues.

A full description of the focus groups, including the protocols and details of each session, is included as Appendix A. Participants were largely solicited via an announcement in a traffic blog affiliated with the local newspaper and social media postings.[69]

The literature search and the focus groups worked in tandem to inform the survey in order to make the survey as relevant as possible for the case study. For future projects, consideration should be given to the need for focus groups, mainly to help understand how commuters in the residential catchment of the corridor think about their options and to identify the language they use to describe what they do—which should then flow forward into any rewording needed for the survey.

SURVEY INSTRUMENT DEVELOPMENT

An essential part of the Method is the conduct of a representative sample survey of corridor citizens to gain empirical understanding of their use of the corridor, their response to existing congestion, how they would respond to removal of the congestion, whether they are the sort of person who would travel as a passenger, and what amount of payment would be required to offset any reluctance to doing so.

The survey instrument was developed in the popular and well-used SurveyMonkey.com service. There were 104 questions, but any one respondent would answer only about 30 of them because there were a variety of pathways that could be taken through the survey, depending on answers to branching questions. The survey was tested by colleagues outside the project team and modified based on their feedback. It was further tested by sending to a small initial sample (see the sampling methodology) and further modified after evaluating the responses.

SAMPLING METHODOLOGY

Initial plans had anticipated surveying commuters and reaching them via major employers on the corridor or by hiring relatively inexpensive online survey providers from San Jose State University or other commercially available providers. The project team was concerned about the ability to target such services reliably on a specific catchment as narrow as a few zip codes. As the project progressed, it became clear that the focus should anyway be broader than just existing commuters in order to connect with people who might start to use the route if congestion went away.

The project team explored the idea of a random sample of residential properties based on the property tax assessment roll. Such a sample could be truly random, as all properties, and therefore all people, could have an equal probability of being selected. To keep costs to the minimum, it was envisaged that the survey itself would be administered online, but the sample would be obtained by visiting randomly selected addresses and engaging people to request participation, leaving visiting cards for people who were not at home, and returning several times until the desired engagement could be achieved, and hopefully the resident would agree to do the survey. It was hoped that a community service organization in the catchment would provide the delivery and engagement service, however the team was unable to engage the support of such a community service organization. The sampling and engagement process described above is what the project team recommends for future projects, but using paid staff rather than relying on a community service organization for delivery and engagement.

For the case study a less reliable method was used: people were selected at random from the registered voter list. See the case study for a full description. This method introduced self-selection bias into the sample.

V. CASE STUDY

CASE STUDY ROUTE CHOICE

In order to develop a realistic methodology, the project team needed a route to focus on that had some level of traffic congestion that might be responsive to congestion-clearing payments. A number of different routes were suggested, including State Route (Highway) 92 from Half Moon Bay to San Mateo, State Route 4, State Route 17, Highway 101, Interstate 680, and Interstate 880.

Highway 92 is a two-lane east–west route through rolling hills and small mountains across the San Francisco Peninsula connecting Highways 280 and 101 with Highway 1 (see Figure 11) and is known for significant traffic congestion. The case study route is highlighted in Figure 11 by the red oval and is described as 'Highway 92 from Route 1 to Highway 280'.

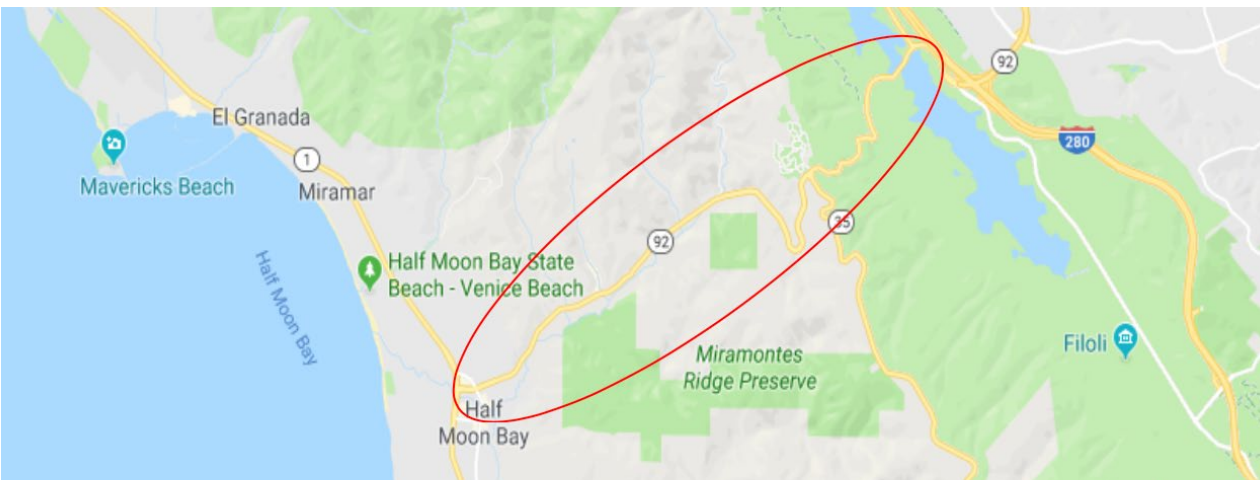


Figure 11. Highway 92 from Half Moon Bay to Interstate 280

The project team selected Highway 92 as the focal route based on several criteria:

- Existence of significant congestion
- Data available about traffic flows
- Simplicity of the catchment for surveying residents
- Simplicity of the route, not having:
    - One or more alternate routes
    - Existing treatments such as carpool lanes and tolled express lanes that might make it more difficult to evaluate traveler response to the proposed CCPTP solution

Therefore, north–south-oriented highways with parallel routes were discarded as options because of the complexity introduced where the impact of a potential intervention on one route might divert traffic from the parallel route. For example, this criterion eliminated

Highways 280 and 101 (see Figure 12) and Highways 680 and 880 (see Figure 13). This is not to say that parallel routes should always be a criterion for route rejection, but that for the development and initial testing of the Method the project team had limited resources and wished to avoid the added complexity parallel routes would bring.

Additionally, Highway 680 has a variable tolled express lane. Carpool lanes currently exist on I-880, and these are currently being converted to tolled express lanes.

Highway 92 has no parallel route. Users of Highway 92 for a morning commute would all come from the single Coastside catchment that was easy to define, being the City of Half Moon Bay and the surrounding communities–there were no other likely sources of commuter traffic on the route. Highway 92 traffic counts were available from the Caltrans website.

That there was congestion to be eliminated was clear from the City of Half Moon Bay planning documents, which said:

> *"During peak periods Highways 1 and 92 are heavily congested, often extraordinarily so during extended weekend peak periods."*[70]

> *"In addition to vehicular trips associated with commuting and recreation, a significant number of large trucks use the same routes. Trucks transport agricultural products out of the area to market. Deliveries to the Ox Mountain landfill as well as transport of sand and gravel from the Pilarcitos Quarry—both of which are located north of Highway 92 east of the city limits—further contribute to a significant presence of truck traffic. Highway 92 is a curving road with increasing grade as it traverses east. Trucks that use these routes affect visibility, overall speed, and volume characteristics, especially when present in concentrations and overlapped with commute or recreational traffic including that associated with commercial entities and residences that take access from Highway 92."*[72]

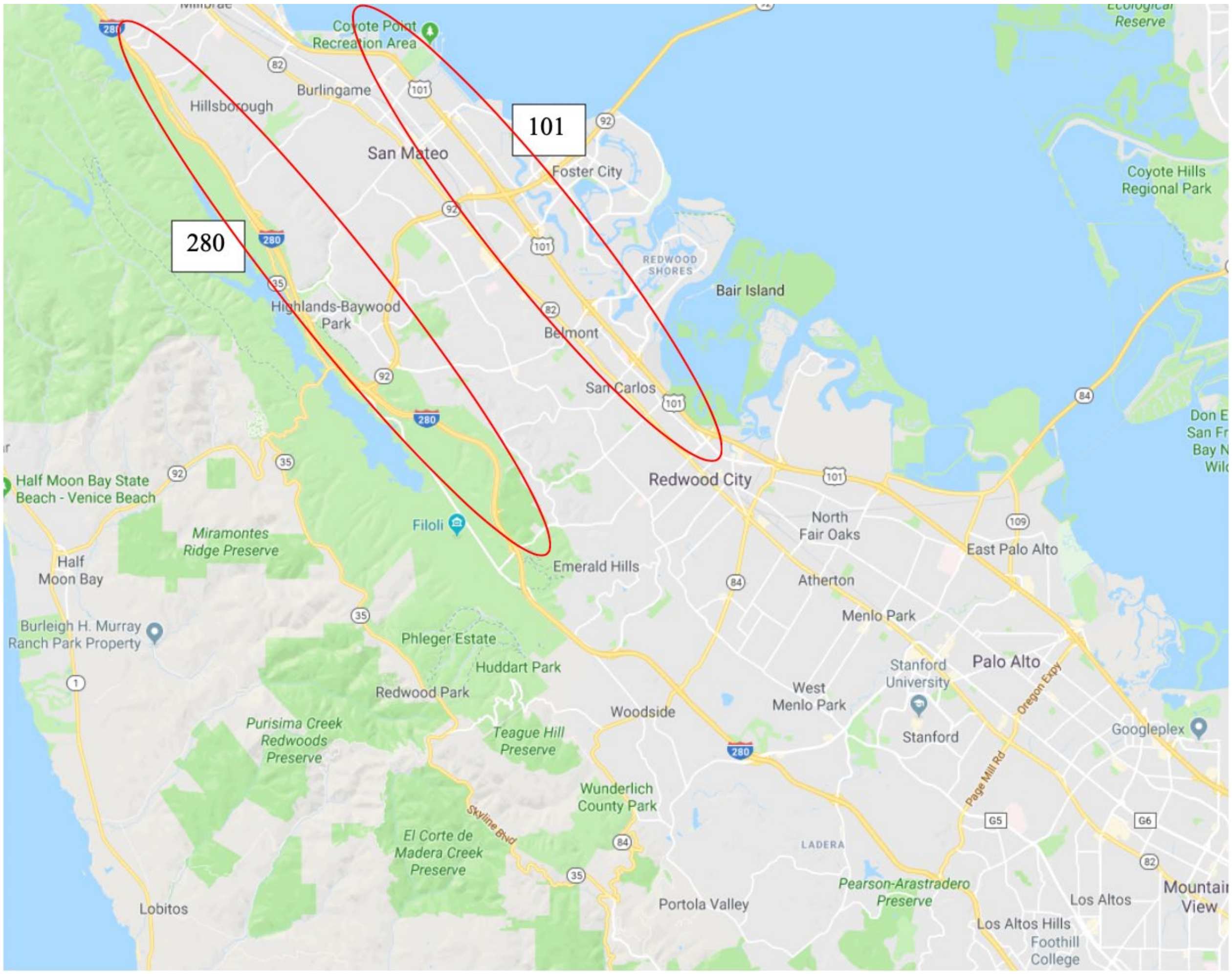


Figure 12. Highways 280 and 101

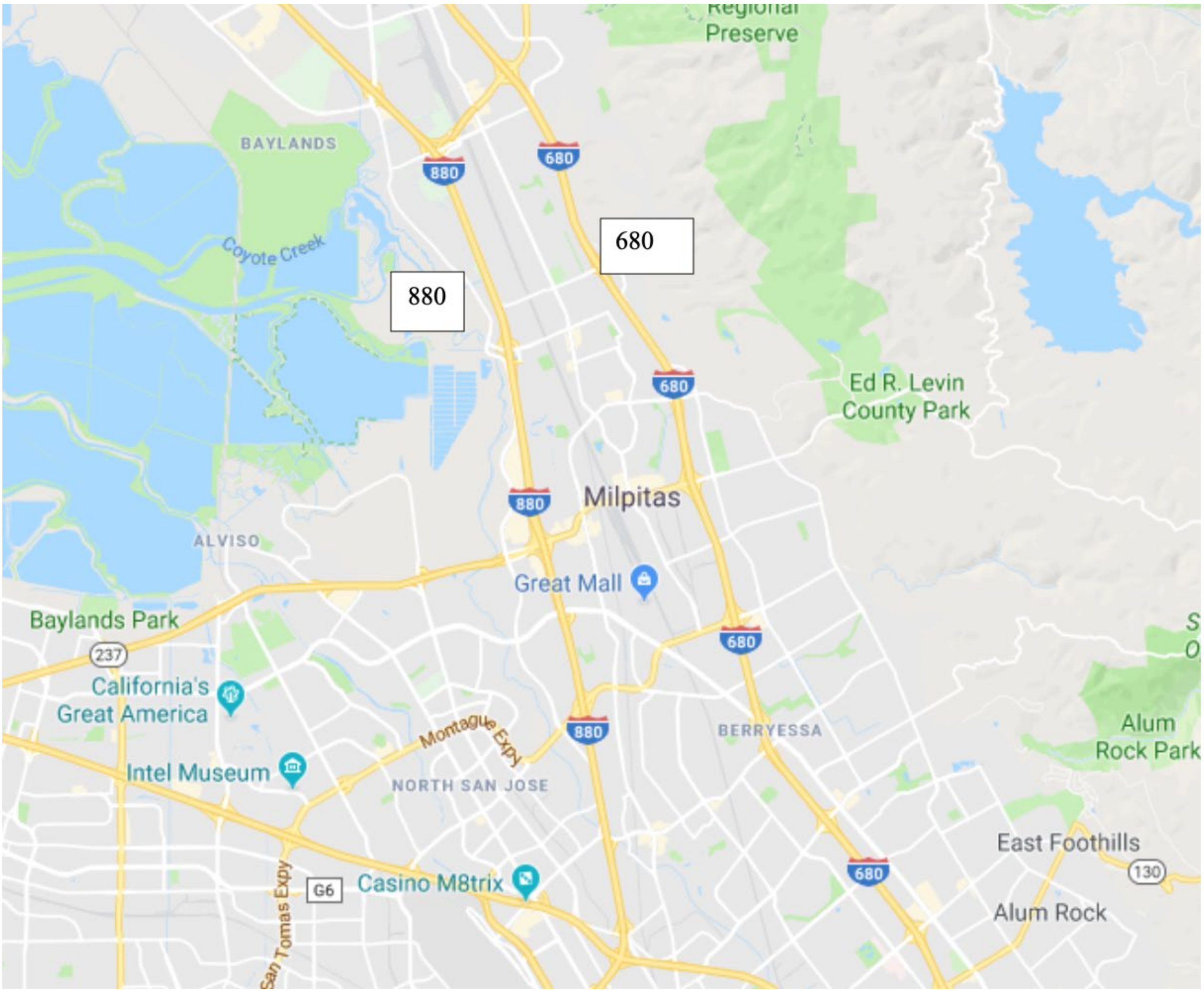


Figure 13. Highways 680 and 880

CASE STUDY DEVELOPMENT

The project team had viewed some statistical data for Highway 92 prior to making the route choice. However, it became apparent later that the available information did not meet all of the initial criteria for evaluating a route. Seeing a route listed on the Caltrans website does not mean that there will be the same level of information available as for any other route so listed. Also, as the project progressed, the team realized that some of the necessary information is not collected for any route. This gap is a reflection of the fact that the CCPTP approach has not previously been considered, so information required by such an approach is simply not collected.

The best information the team could access for the case study route was a time series of one-hour counts, shown in Table 3: counts at the bottleneck location in 2003, 2006, 2009, and 2012, showing the number of vehicles that passed through the bottleneck each hour. There is no additional detail available either in narrower time bands or in the composition of the traffic.

Table 3. Traffic Counts at the Bottleneck

Average Traffic Volumes Eastbound, Tuesday to Thursday

Count dates	5–6 am	6–7 am	7–8 am	8–9 am	9–10 am
2003 May	353	985	1,457	1,217	917
2006 June	742	1,547	1,846	1,631	1,465
2009 April	276	749	1,227	1,107	859
2012 July	347	867	1,231	1,182	940

Note that the time series in Table 3 ends in 2012, six years before this project. Also note that this route has had a long-standing reputation for bad traffic congestion: for example, it was known for its congestion by three out of four members of the project team. It was based on this reputation that the route was chosen—the lack of statistical information mentioned above was realized much later. After some difficulty and delay in finding other sources, the team did finally obtain a one-day weekday count of traffic on SR 92 where it crosses Main Street and found that the results were consistent with the older counts described above and below.

The paucity of data is expected to be a common problem, so the team developed some innovative solutions for resolving the data problem, rather than changing to a different case study route. These solutions are discussed in the next section.

OBTAINING BETTER TRAFFIC DATA

Caltrans advised that they had count data for adjacent locations over a longer period of time. These were obtained and analyzed. Table 4 shows traffic counts on Tuesday mornings at an adjacent location that had a high correlation with the case study bottleneck throughput, as well as some relatively recent counts. The team decided to use the average of the 2017/2018 counts from this location as a basis for analysis.

Early in the project, it was thought that a rate of departure from the queue (through the bottleneck) of around 1,400 vehicles per hour seemed low. Corroborating evidence was sought. Also, the team noted that this apparent limit has been impacting this traffic for the past 17 years and seems to be consistent regardless of the time of year.

The team contacted a commercial provider of traffic information and were advised that the sources the commercial provider typically relied on for robust data were not available for the case study route due to the relatively low volumes of traffic on the route.

The team contacted Caltrans who advised that they are opting to use Google Traffic for much of their own initial analysis of traffic conditions as a much lower-cost and possibly more flexible method of data acquisition compared to the usual pressure-sensitive tubes laid across the road. The team therefore turned to Google Traffic to see what could be learned about the existing traffic at the bottleneck. The objective was to learn about volumes of traffic, the existence of queues, and the amount of delay. Two sources were used: Google

Typical Traffic and Google Maps Live Traffic.

Table 4. Traffic Counts East of the Bottleneck but with High Correlation

Tuesday Mornings, Averages of Actual Readings, at the 'Ahead' Location

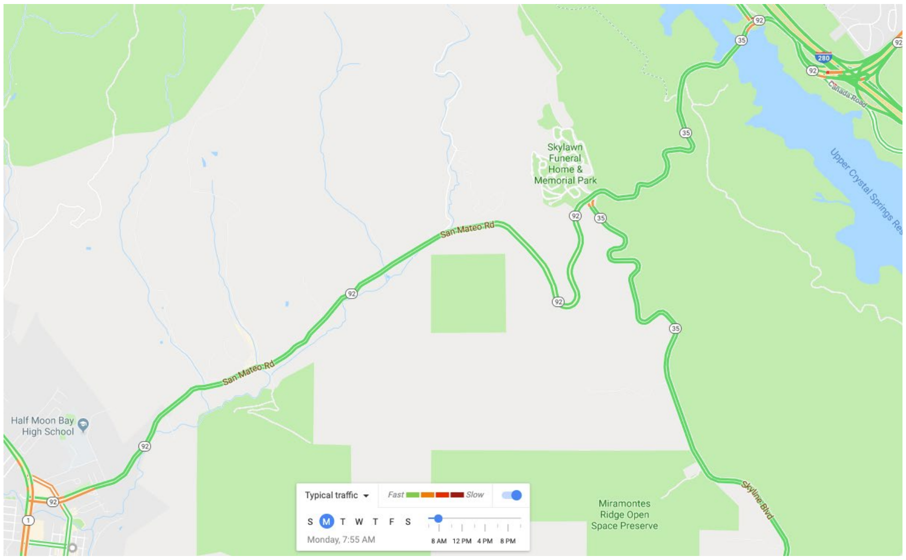
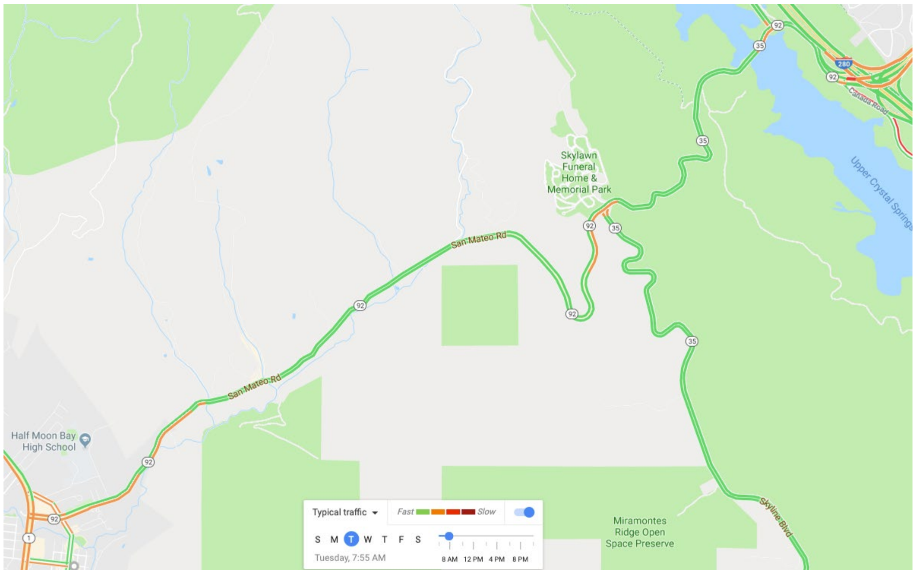
Month	5–6 am	6–7 am	7–8 am	8–9 am	9–10 am
2002 November	340	839	1,370	1,356	978
2003 February	375	970	1,399	1,196	927
2003 May	306	920	1,378	1,267	915
2003 August	329	845	1,280	1,198	947
2005 October	381	984	1,602	1,388	1,027
2006 January	120	344	827	1,433	1,341
2006 April	869	1,843	1,437	1,231	1,297
2006 July	602	1,229	1,378	1,463	1,417
2008 October	293	819	1,351	1,156	933
2009 January	320	813	1,316	1,156	887
2009 April	292	763	1,379	1,212	968
2009 July	300	701	1,220	1,165	923
2011 October	366	812	1,240	1,519	1,063
2012 January	325	780	1,256	1,407	943
2012 April	314	752	1,365	1,233	999
2012 July	359	877	1,325	1,299	1,035
2014 October	361	896	1,311	1,243	974
2015 January	127	389	978	1,463	1,354
2015 July	419	881	1,308	1,267	1,164
2017 October	452	1,027	1,558	1,504	1,242
2018 January	443	909	1,386	1,288	934
2018 April	448	966	1,337	1,177	1,128
2018 July	473	960	1,347	1,244	1,194
Average 2002 to 2018	374	883	1,319	1,298	1,069
Std Dev 2002 to 2018	149	280	159	118	163
Average Oct 17 to July 18	454	966	1,407	1,303	1,125

Google Typical Traffic

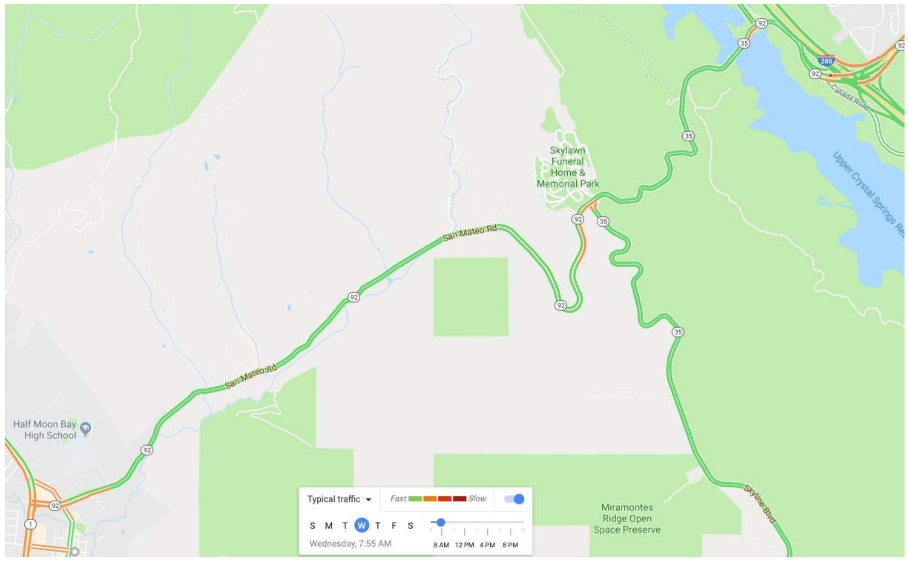
Screenshots were captured showing typical traffic from Google. For example, Table 5 shows the screenshot for each weekday at 7:55 am, showing the full route from Highway 1 to Highway 280 (paralleled with a red arrow on the image from Monday). It can be seen that

Tuesday is the worst day of the week. The team decided to focus on Tuesday as the main day for which to develop a comprehensive understanding of traffic flows, against which to test the CCPTP solution concept.

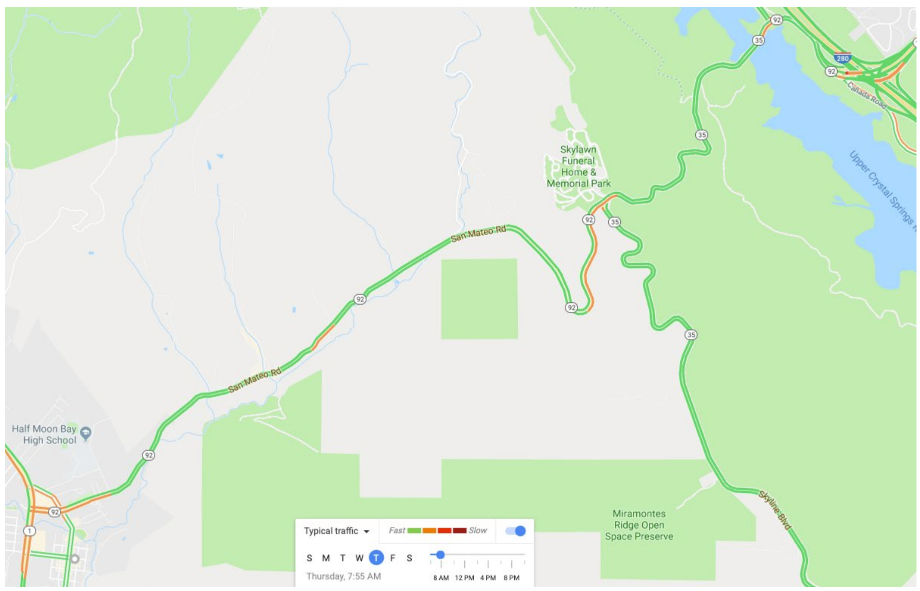
Table 5. Google Typical Traffic. SR 92: 7:55 am for Five Weekdays

Monday	
Tuesday	

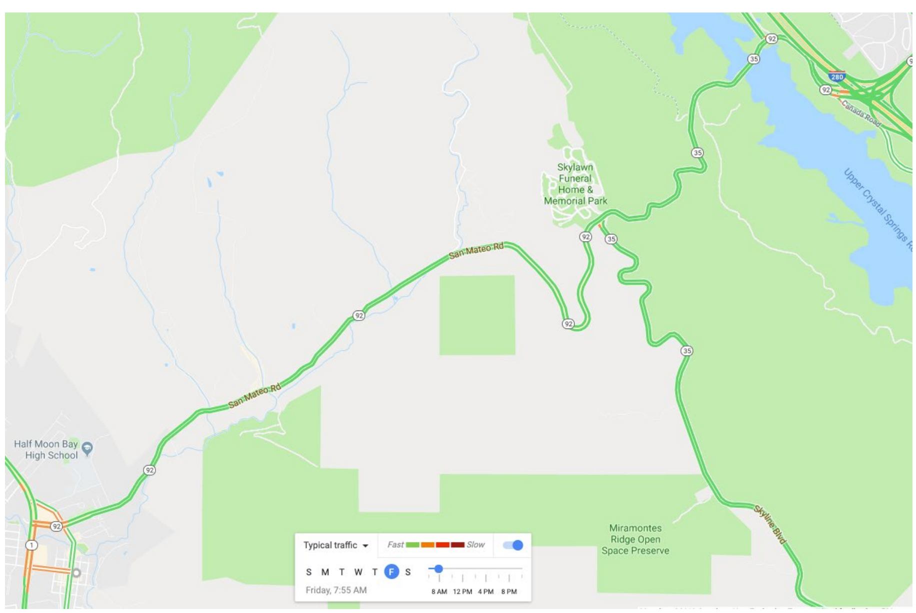
Wednesday



Thursday



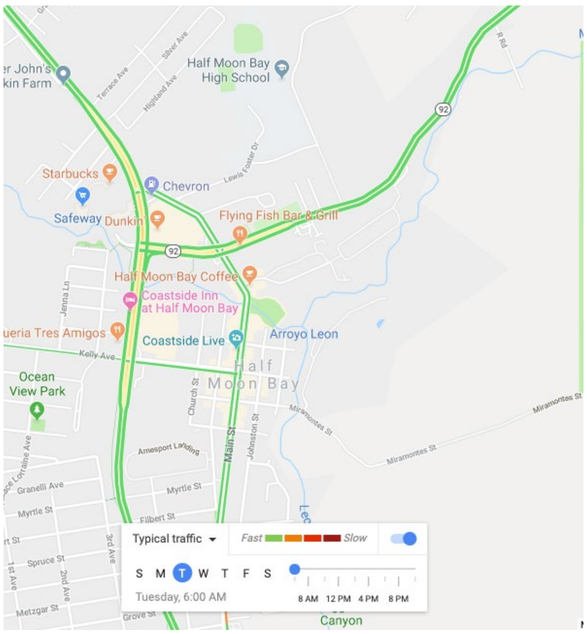
Friday



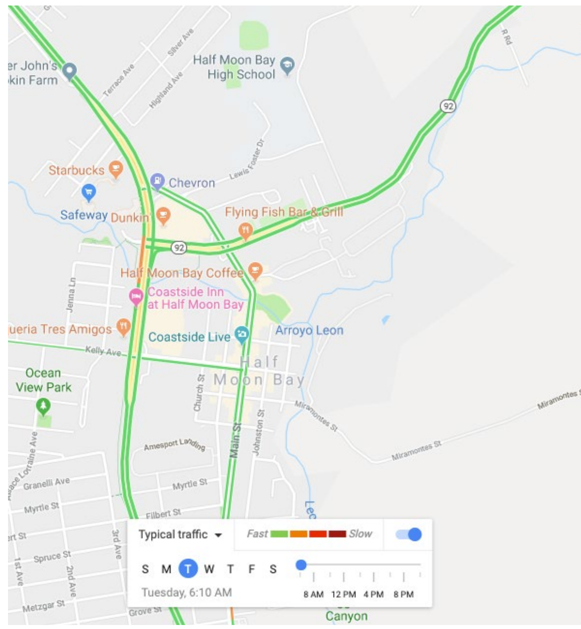
Typical traffic was observed (on Google Maps) for a variety of different times on Tuesday mornings to investigate whether the size and duration of queues could be determined.

The congestion issue clearly occurs around the intersection of Highway 1 and SR 92. Screenshots were captured of this more focused geography looking at the typical traffic situation every ten minutes from 6 am to 9 am. Tables 6 to 11 show typical Tuesday traffic on Highway 1 and SR 92 at Half Moon Bay from 6 am to 9 am.

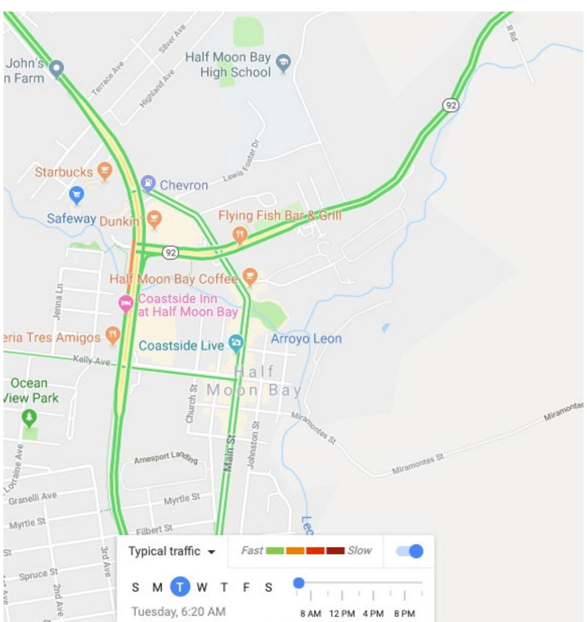
Table 6. Typical Tuesday Traffic. Highway 1 and SR 92 at Half Moon Bay. 6:00 am to 6:30 am



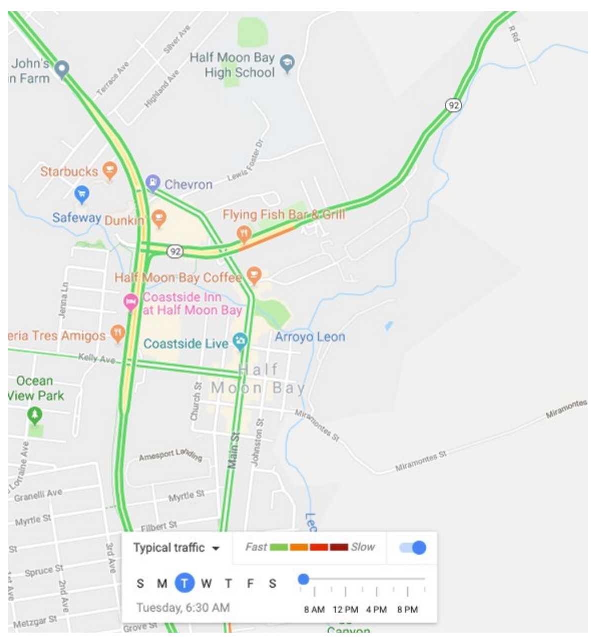
6:00 am



6:10 am



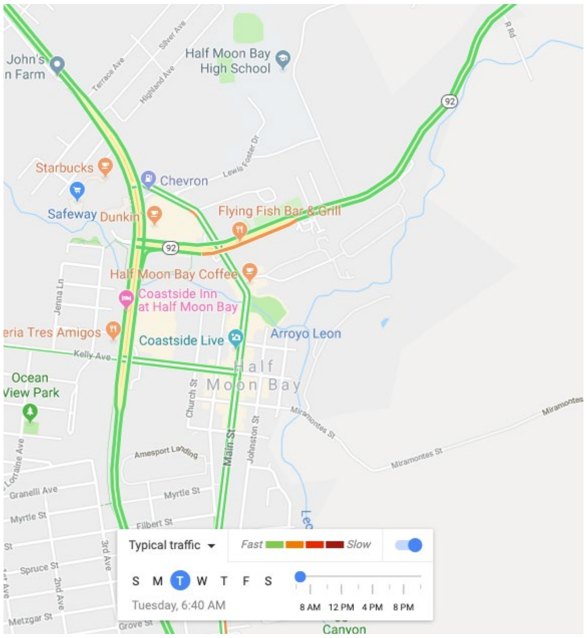
6:20 am



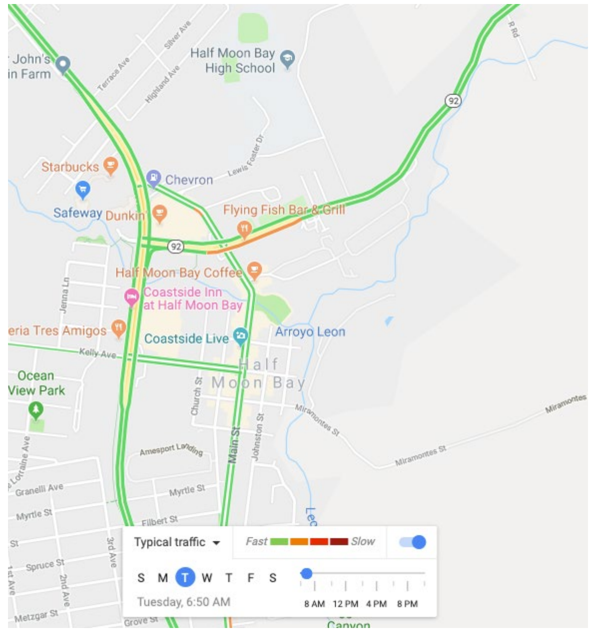
6:30 am

Table 6 shows traffic at 6:00 am, 6:10 am, 6:20 am, and 6:30 am. There is no real delay at these times, except for outside the Flying Fish Bar and Grill where the traffic is merging into a single lane, at 6:30 am.

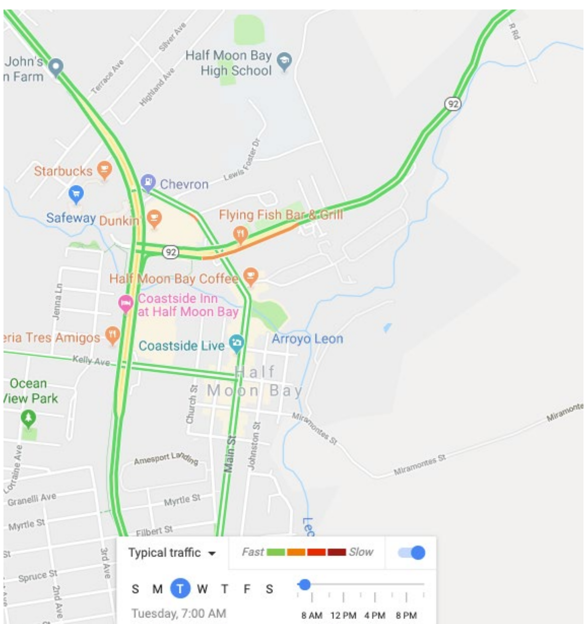
Table 7. Google Typical Tuesday Traffic. Highway 1 and SR 92 at Half Moon Bay. 6:40 am to 7:10 am



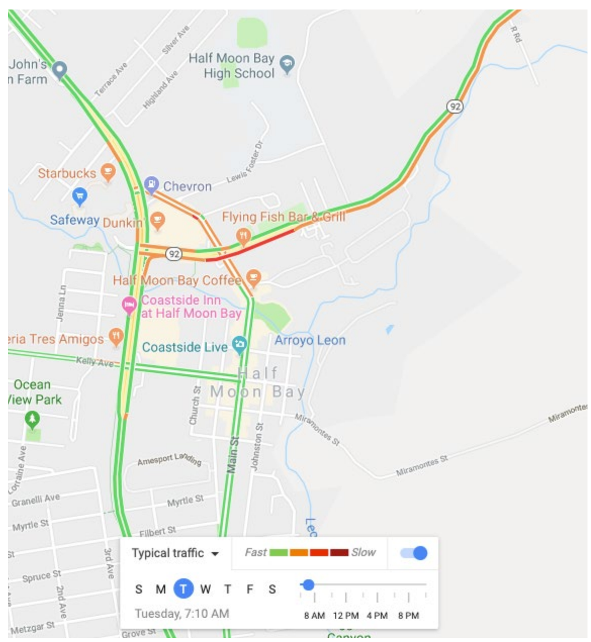
6:40 am



6:50 am



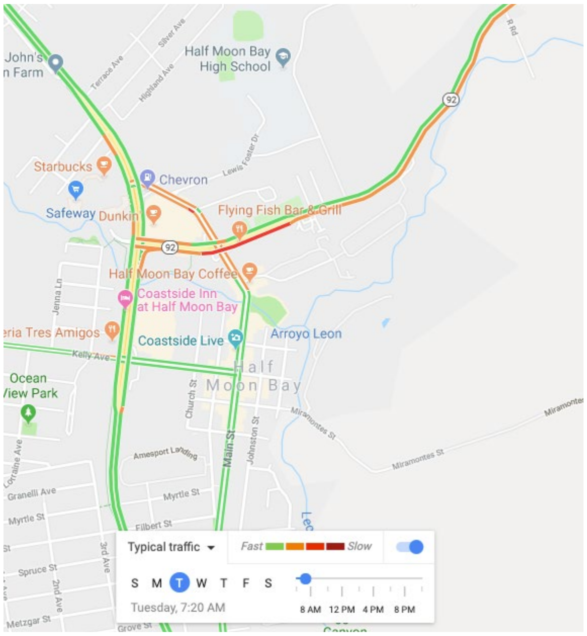
7:00 am



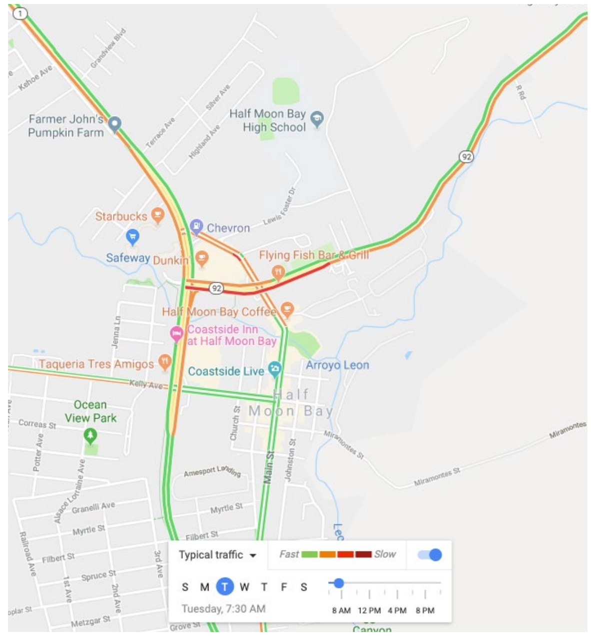
7:10 am

Table 7 shows 6:40 am, 6:50 am, 7:00 am, and 7:10 am. The traffic backs up from the merge point and is slower moving (orange) across Main Street. There is a traffic signal at this intersection. By 7:10 am, the traffic on Main Street is impacted, as is the slower traffic back to Highway 1. Next to the Flying Fish the traffic is slow (now red, compared with 'slower' (orange) earlier). There is also some back-up on Highway 1.

Table 8. Typical Tuesday Traffic. Highway 1 and SR 92 at Half Moon Bay. 7:20 am and 7:30 am



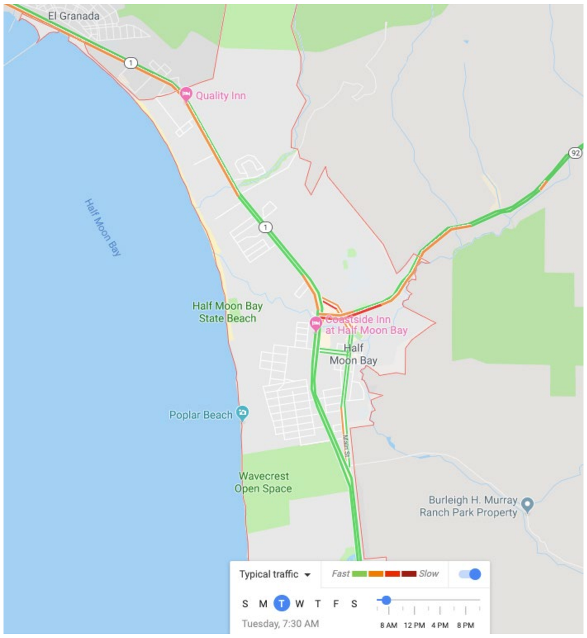
7:20 am



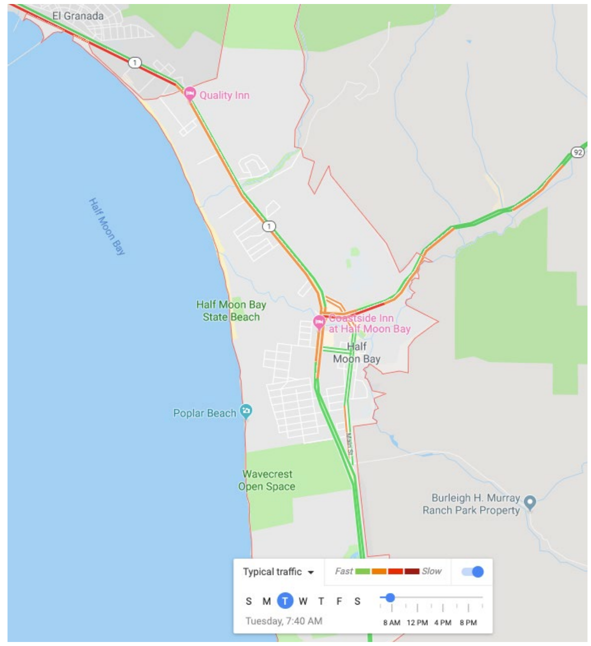
7:30 am

Table 8 shows maps for 7:20 am and 7:30 am, showing that the slower traffic extends a long way up the 92 and back along Highway 1 both from the north and the south. Main Street continues to be congested with traffic seeking to go in both directions: to Highway 92 and to Highway 1.

Table 9. Table 10: Typical Tuesday Traffic. Highway 1 and SR 92 at Half Moon Bay. 7:30 am and 7:40 am (wider view to include El Granada)



7:30 am

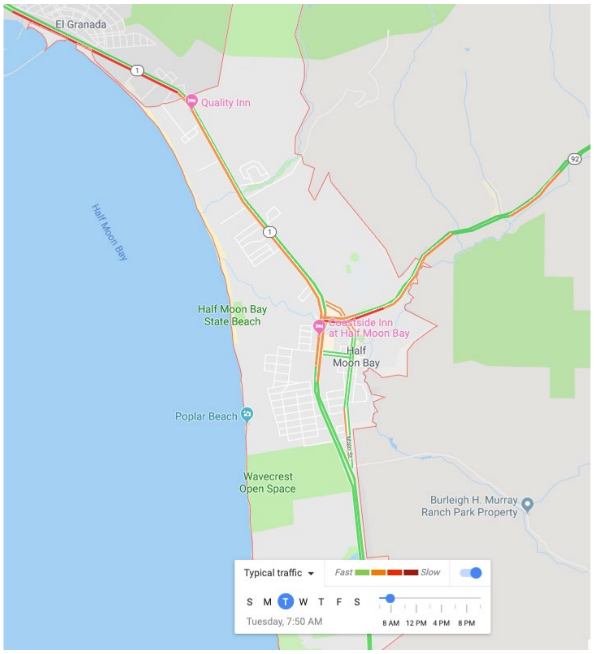


7:40 am

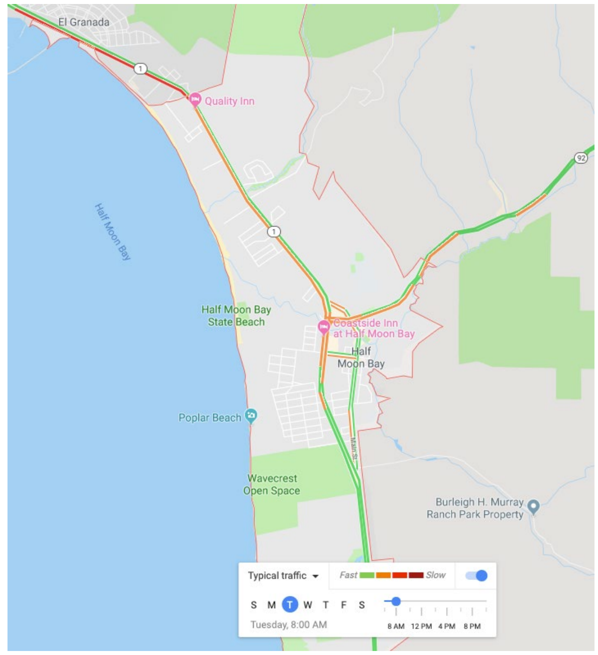
Realizing that at 7:40 am the traffic backs up all the way to El Granada, the scale is changed to reconsider the situation as it appears at 7:30 (see Table 9). There is a tranche of slower-moving traffic coming from El Granada that by 7:40 am represents a full slower-moving southbound lane over the whole distance. It appears that there is some form of bottleneck near the Quality Inn on the south side of El Granada. Perhaps the left-turn lane at Medio Ave. is not long enough.

Also note that Highway 1 is a minor road at this location with local traffic being able to join or leave, perhaps contributing to the lower speeds.

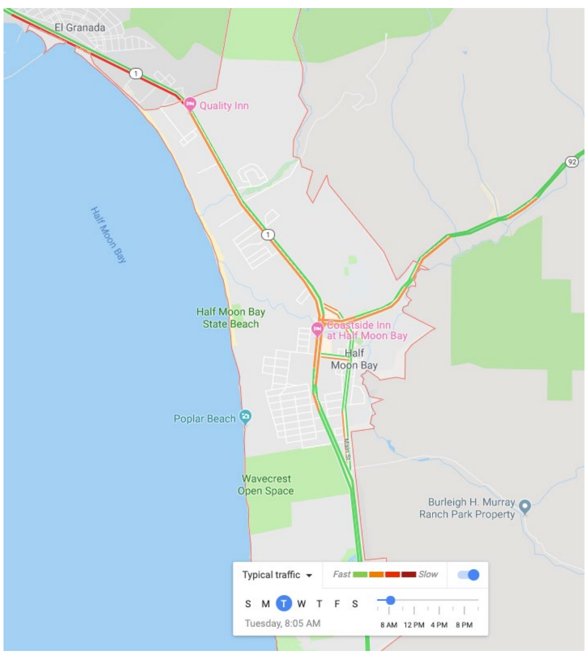
Table 10. Typical Tuesday Traffic. Highway 1 and SR 92 at Half Moon Bay. 7:50 am to 8:15 am



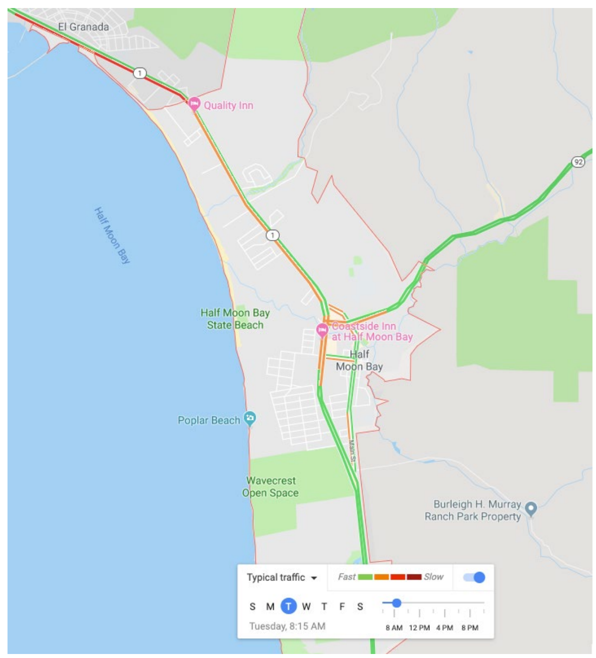
7:50 am



8:00 am



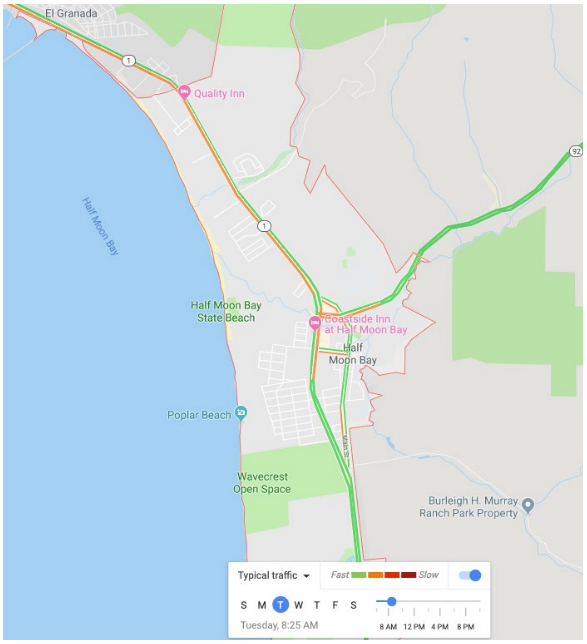
8:05 am



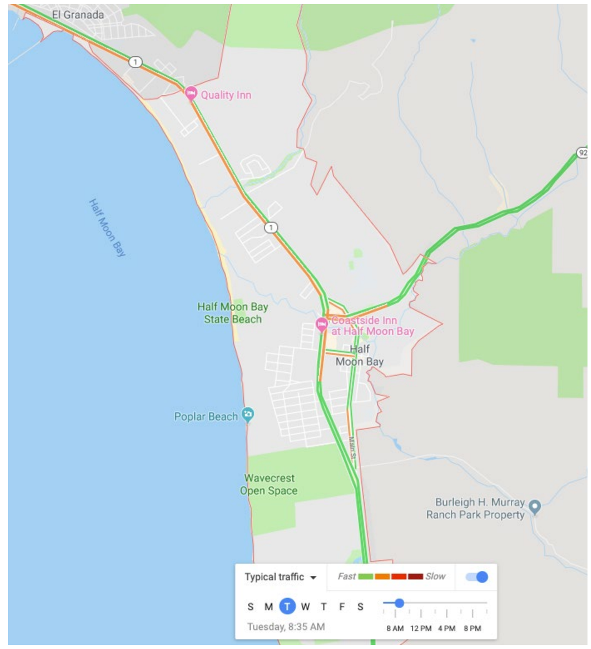
8:15 am

The maps for 7:50 am, 8:00 am, 8:05 am, and 8:15 am (Table 10) show that the traffic speeds up slightly at the Highway 1/92 intersection but continues to be slow through El Granada, due to a tranche of traffic that is headed southbound to the Highway 1/92 intersection.

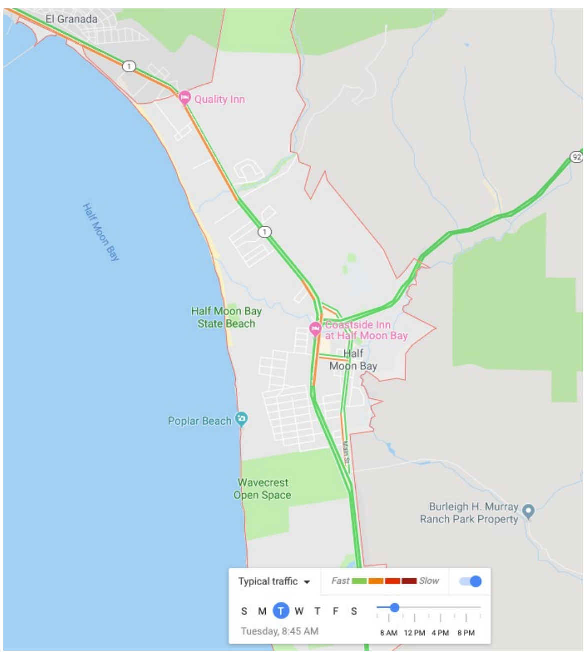
Table 11. Typical Tuesday Traffic. Highway 1 and SR 92 at Half Moon Bay. 8:25 am to 8:55 am



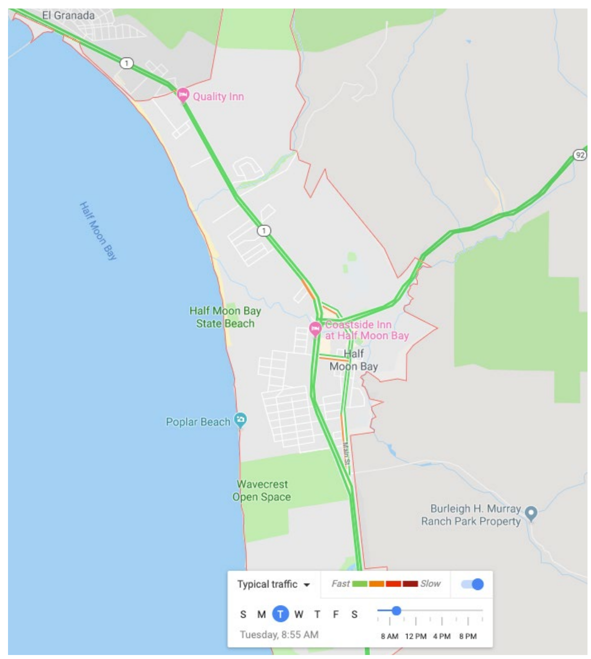
8:25 am



8:35 am



8:45 am



8:55 am

Table 11, comprised of screenshots for 8:25 am, 8:35 am, 8:45 am, and 8:55 am, shows the dissipation of the accumulated traffic as it speeds up and the bottleneck is resolved by 8:55 am.

Interpreting Google Typical Traffic

Google gives four typical traffic speeds: from green for fastest to dark red for slowest. The average speeds that correspond with these values are not available. Nor are values to associate with the progression to slower (orange) and slow (light red). Light red can be interpreted as ‘bad,’ but clearly it is still moving. The project team attempted to find out the algorithm behind these colors (how Google Maps decides which color corresponds to which speed), and how many days of observations are averaged together and whether any weightings are applied. These efforts were unsuccessful–while Google has information online about typical traffic, it does not include the algorithm. Hence, the team does not know what conditions it would take to get to an average of dark red, nor whether the values are different if there are different posted speeds, or how quickly changes to the traffic (over time for the same time and day) would change the ‘typical’ traffic displayed.

The project team expected that the length of the queue could be determined from these maps, if it were safe to assume light red is in fact a queue, by using the scale of the map, and converting that scale into a number of vehicles.

It was noted that there are two bottlenecks in these maps: the one at Highway 1/92, and the one next to the Quality Inn towards El Granada. The project team considered including both in the project. It was decided that changing the average occupancy at the Highway 1/92 bottleneck could result in changing the average occupancy at the Quality Inn, so both might be impacted through the same set of incentives.

As a ‘business rule’ for congestion-clearing payments to passengers, it was noted that a distance-based component could be incorporated in the incentive, so that people who travel as passengers for greater distances receive larger incentives. In this way it would be expected that people further from the bottleneck would benefit from making the effort to travel as a passenger from as close to home as possible. Such a higher incentive for people who travel as passengers for the whole distance to the I-280 would encourage increased sharing from points farther north such as El Granada and reduce the impact of an intervening bottleneck (such as the one that can be seen next to the Quality Inn). However, this additional incentive has not been included in the modeling for the case study.

Google Maps Live Traffic

The uncertainty referred to above regarding the algorithms used to determine typical traffic on Google Typical Traffic led to a parallel effort by the project team based on the more easily understandable Google Maps Live Traffic. In this case it was found that screen capture software could be used in an automated routine to grab an image of Live Traffic every few seconds; these images could then be consolidated and compressed to form a time-lapse video of the peak period traffic. Several such videos were made.

An example video can be viewed here: **https://tinyurl.com/HMBvideo**

Estimating queue length

Based on the aforementioned work, the longest queue was calculated to be about 287 vehicles long, at 7:25 am, based on the Google map as shown in the screenshot in Figure 14. The segments measured were those that the automated screen captures revealed were highly congested. What surprised the project team was that the typical traffic displayed by Google Typical Traffic varied over time to a much greater degree than expected. The team therefore decided that Google Typical Traffic is of questionable value for drawing conclusions about queue length at any given time on any given day of the week. Compare Figure 14 and Figure 15, screenshots of typical traffic at the Half Moon Bay bottleneck at a similar time of day and day of week, taken within a couple of weeks of each other. They are quite different both in terms of the colors representing speed and the apparent length of the queues.

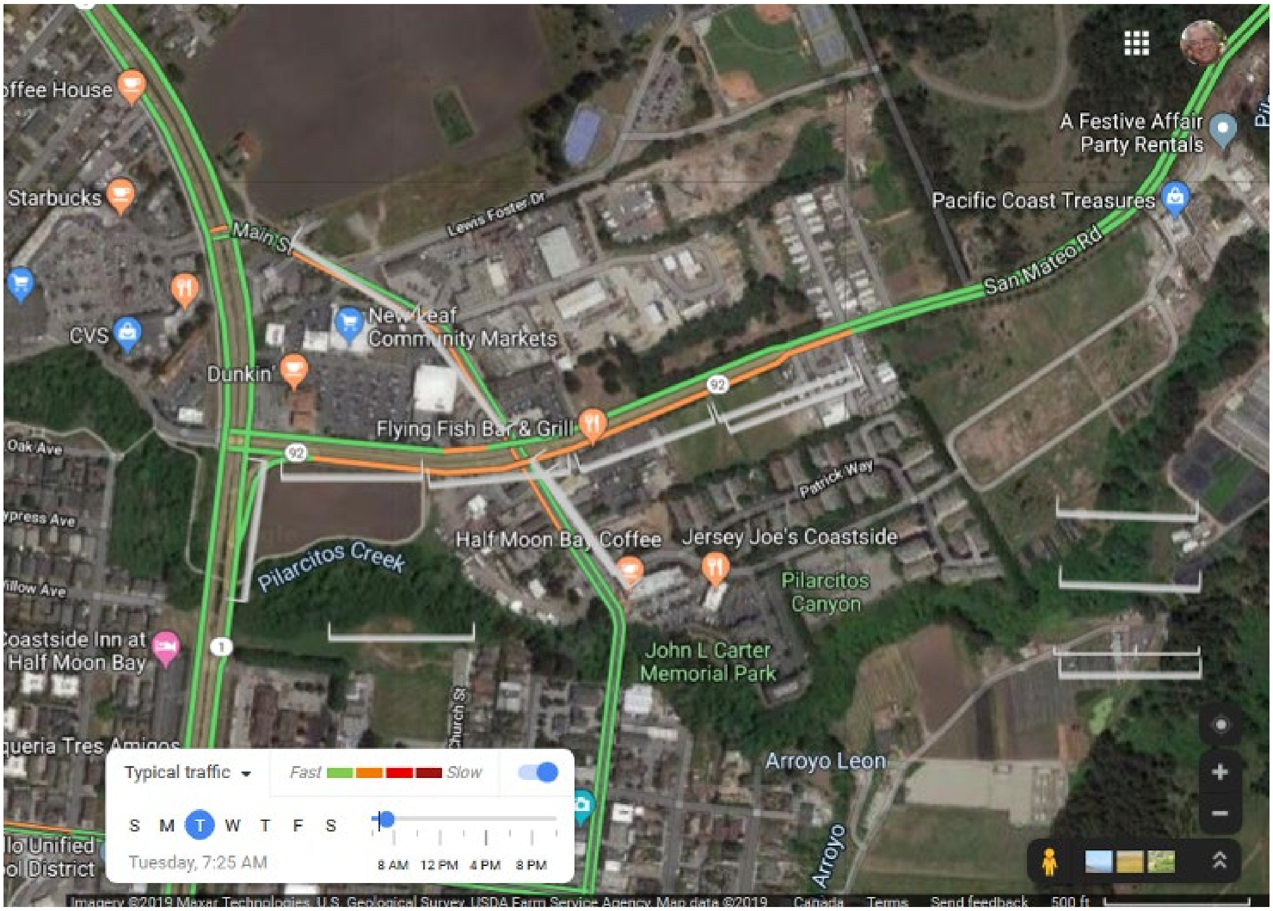


Figure 14. Typical Tuesday Traffic, Half Moon Bay. 7:25 am (showing bars used for measuring the queue)

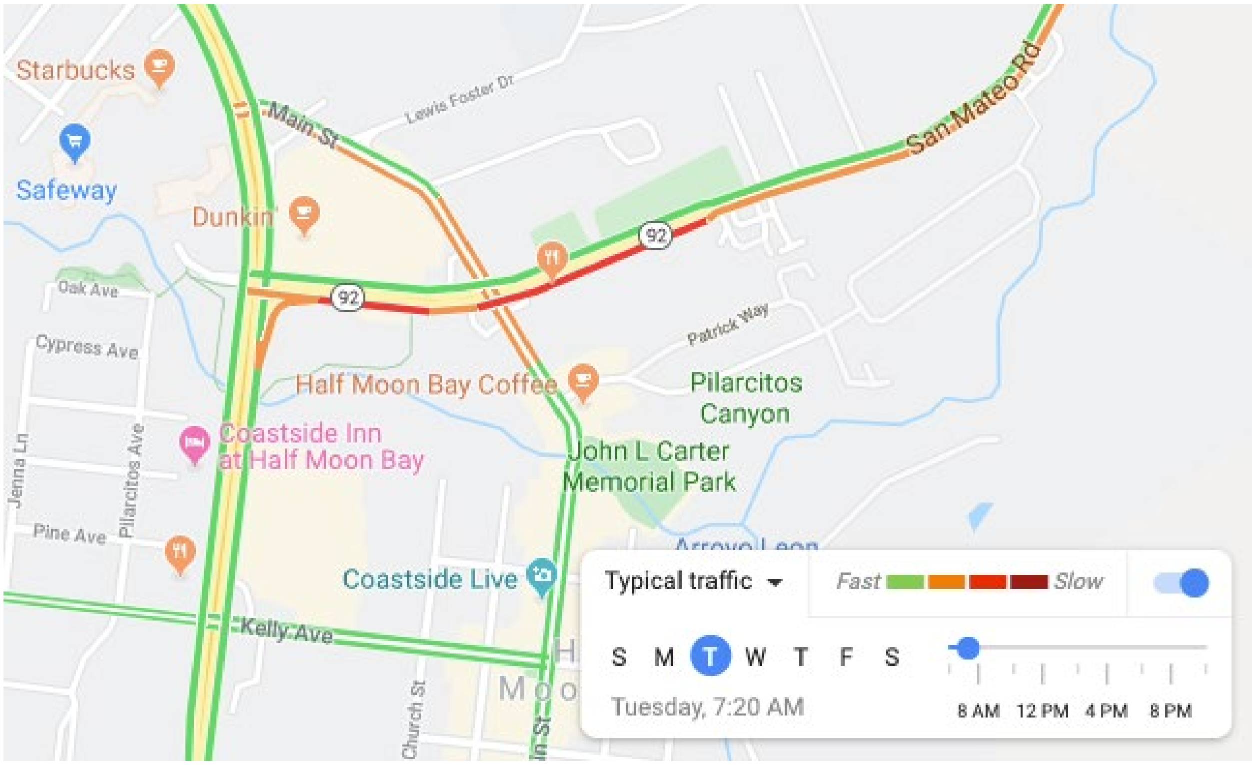


Figure 15. Typical Tuesday Traffic. 7:20 am

The difference between these maps presents a serious limitation on the use of the Google Typical Traffic tool for estimating queue length. Google Typical Traffic should be used with caution and should not be a replacement for actual measurement on the ground.

Using the typical traffic in Figure 14 and knowledge from the live traffic videos, however, the maximum queue was estimated at 6,500 lane feet, or 1.23 miles. This distance was translated to a number of vehicles using an estimated of jam density (vehicles per mile) based on recent Google Maps screenshots of slow-moving traffic at border crossings between the U.S. and Canada, which averaged 233 vehicles per mile (see Figure 16). A queue length estimate of 287 vehicles was therefore established and compared well with modeling based on the survey.

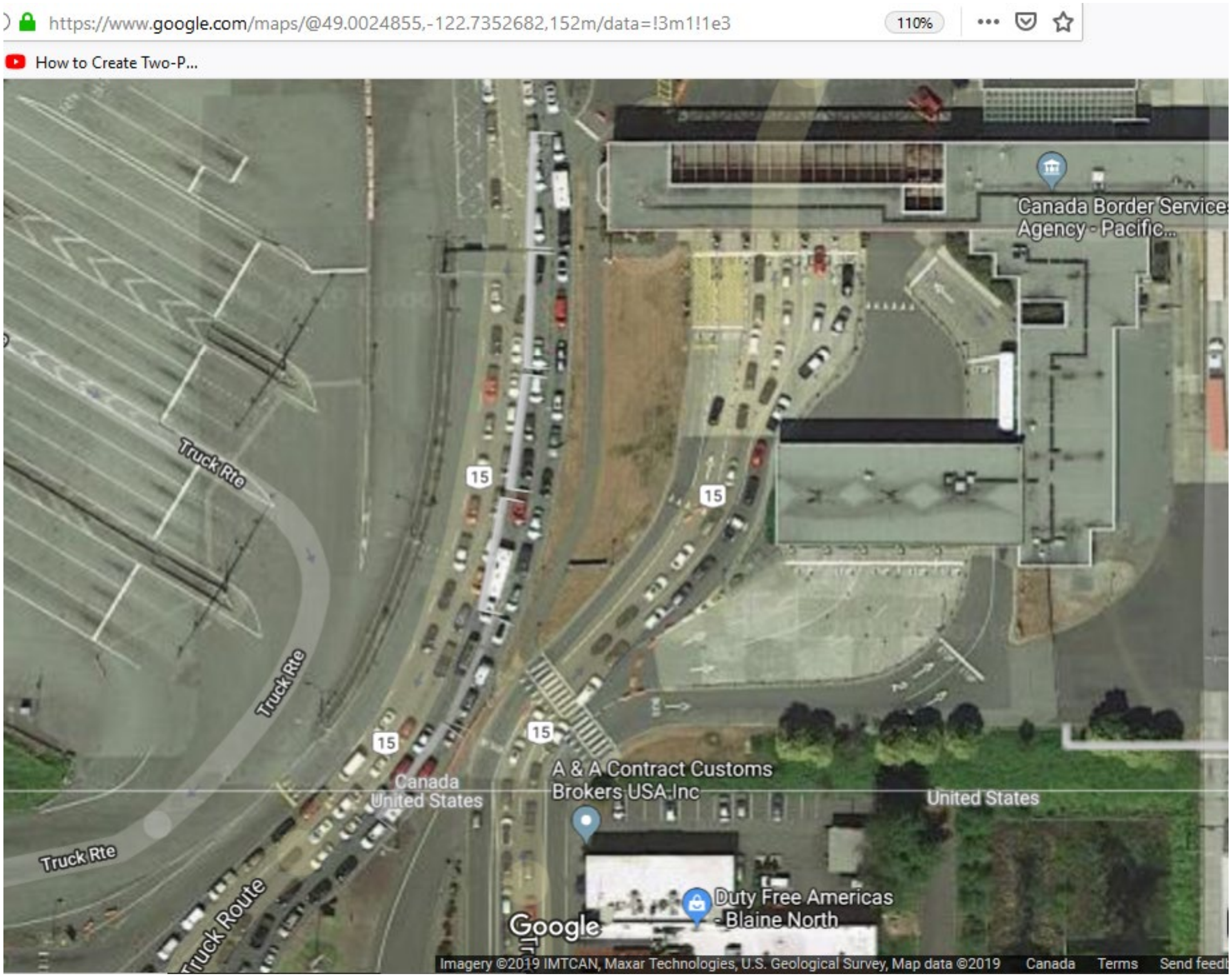


Figure 16. Screenshot of Google Maps Satellite View at U.S.–Canada Border

Selecting a representative sample and testing the survey

The sample for the survey was extracted from the registered voter list for the Half Moon Bay coastal communities commute shed that uses the SR 92 connection across San Mateo County between the Pacific Coast and Silicon Valley. Because of the somewhat isolated location, it is logical that all commuter traffic on the route would be from this catchment. The voter list was readily available from San Mateo County, held an estimated 80% of all people aged 16+, and contained both email and phone numbers of registered voters in a Microsoft Excel format.

Experience found that, compared to expectations, a smaller proportion of the registered voters had email addresses, and fewer had phone numbers. Later experience revealed that almost none of the phone numbers worked. It was also found that the age distribution of people with email addresses was very similar to the age profile of the whole database and in turn was similar to the age profile of people in the target communities. It was therefore anticipated that sending an on-line survey link to people with email addresses should yield a sufficiently representative sample.

A sample of voters having email addresses was extracted from the database using a Microsoft Excel spreadsheet random selection method, as follows:

- Each voter on the database was assigned a unique number, sequentially, from 1 to ‘n’ (the total number of voters on the database).
- The formula “=RANDBETWEEN(1,n)” delivered a number, and that was used to look up the details of the voter who had been assigned that number.
- The =RANDBETWEEN formula was copied for the required number of rows to deliver the sample.
- The list so generated was compared to the entire database on the basis of age distribution and was found to be broadly similar.

The survey was tested with an initial selection of 50 email addresses via SurveyMonkey. After revision, the survey was distributed to a larger sample. Analysis suggested that further revisions were required. A final revised email survey invitation was sent to 588 email addresses, with response rates as follows:

- 4 (0.7%) were automatically opted out by SurveyMonkey,
- 22 (3.7%) messages bounced,
- 218 (37.1%) invitations were unopened, and
- 344 (58.5%) were opened, and
- 120 (20.4%) surveys were sufficiently completed for meaningful analysis.

From the demographic classification questions asked in the survey, a comparison with available Census data showed that the characteristics of respondents closely matched the total population.

The team was satisfied that the sample was representative. Please refer to the heading ‘Adjusting for self-selection bias’ in the Case Study section for a discussion on the topic of representativeness.

The full survey is reproduced in Appendix B.

Survey analysis

Respondents were asked whether they use Highway 92 between 5 am and 9 am on a typical Tuesday throughout the year; if so, how they use it: which residential community they live in, what time they leave home, where they go and why, what mode of travel they use; and whether they use it every Tuesday or just some Tuesdays.

It is useful to note that there are six main residential communities on the Coastside (the coastal area of San Mateo County from Montara to Pescadero, and survey respondents travel to as many as 25 different destinations, about 15 of which were the destination of more than one respondent.[72] In all cases, travel to these destinations must be via the bottleneck at the junction of Main Street and Highway 92 (it is the only route).

The responses from the above questions were converted into arrival times at the bottleneck, assuming it takes the average amount of time to make the trip from the residential community to the bottleneck, based on the average of the longest and shortest trip times suggested by Google Maps. People who indicated less than a regular weekly trip were assigned a probability of being at the bottleneck on any given Tuesday.

Data from the historic traffic counts (from Table 4) were used to calculate a multiplier to gross up from the probability-adjusted number of respondents to the full traveling population as follows.

1. The average of the 2017/2018 hourly counts was reduced by an assumed proportion for non-commuter traffic (10% was used based on feedback from the City Engineer of the City of Half Moon Bay), delivering the total commuter traffic;

2. The total commuter traffic was divided by the number of vehicles adjusted for the probability of being there on a Tuesday morning from the survey, delivering the multiplier (3,716 / 54.8 = 67.8). See Table 12.

Table 12. Calculating the Multiplier

	5–6 am	6–7 am	7–8 am	8–9 am	Total
Average Oct 17 to July 18	454	966	1,407	1,303	4129.6
Less: Allowance for non-commuter traffic	45	97	141	130	0.0
Average commuter vehicles	409	869	1,266	1,173	3716.7
Probability Adjusted Traffic from Survey					54.8
Multiplier					67.8
Commuter vehicles (modeled)	417	784	1,293	1,243	3737.7
Over/Under	9	(85)	27	71	21.0

The peak average hourly traffic of 1,407 vehicles was divided to calculate an average for vehicles departing the bottleneck each minute, that is, the queue discharge flow rate.

Each respondent's bottleneck arrival time was calculated, and the probability factor was multiplied by the calculated multiplier of 67.8 to derive a number of vehicles arriving at the bottleneck. Each respondent's multiplied arrival at the bottleneck was spread evenly across ten minutes to derive a minute-by-minute count of commuter vehicles arriving at the bottleneck. The spread across ten minutes was an arbitrary method to reflect that if this number of vehicles arrived, they could not arrive all at once. The non-commuter vehicles were added.

Minute-by-minute total flows were calculated, showing the opening queue (if any) for the minute, the vehicles arriving, the vehicles departing, and the ending queue. An excerpt from the model calculations is shown in Table 13.

Table 13. Sample of Queue Length Calculations from the Model

	Starting Queue	Arriving Commuter Traffic	Arriving Non-Commuter Traffic	Total Arriving Traffic	Departures	Ending Queue
7:00:00 AM	50.5	13.6	2.3	15.9	23.5	42.9
7:01:00 AM	42.9	13.6	2.3	15.9	23.5	35.3
7:02:00 AM	35.3	20.3	2.3	22.6	23.5	34.4
7:03:00 AM	34.4	20.3	2.3	22.6	23.5	33.5
7:04:00 AM	33.5	45.8	2.3	48.1	23.5	58.1
7:05:00 AM	58.1	45.8	2.3	48.1	23.5	82.7
7:06:00 AM	82.7	45.8	2.3	48.1	23.5	107.3
7:07:00 AM	107.3	45.8	2.3	48.1	23.5	131.9
7:08:00 AM	131.9	32.2	2.3	34.5	23.5	142.9
7:09:00 AM	142.9	32.2	2.3	34.5	23.5	153.9
7:10:00 AM	153.9	32.2	2.3	34.5	23.5	164.9
7:11:00 AM	164.9	32.2	2.3	34.5	23.5	175.9
7:12:00 AM	175.9	25.4	2.3	27.7	23.5	180.1
7:13:00 AM	180.1	32.2	2.3	34.5	23.5	191.1
7:14:00 AM	191.1	6.8	2.3	9.1	23.5	176.7
7:15:00 AM	176.7	6.8	2.3	9.1	23.5	162.3

The model therefore delivered a quantity of estimated arriving commuter traffic for each hour derived from the survey data. The modeled quantity was compared with the actual flows from the historical counts. The results can be seen in Table 12, above. The purpose of this comparison was to decide if the traffic modeled based on the survey data was a reasonable representation of the real traffic. Considering the small amount of 'over/under' for each hour, (the last row on Table 12), the project team concluded that the model was a reasonable representation of the real traffic on Tuesday mornings.

CURRENT EXCESS TRAFFIC

Each minute that the arriving traffic exceeds the departing traffic, the difference forms part of 'excess traffic.' The arriving traffic can be divided into 'within capacity' and 'excess.' Figure 17 shows the various statistics on a minute-by-minute basis: excess traffic, the resulting queue, and the number of commuters (not vehicles) departing the queue from 7 am to 9 am.

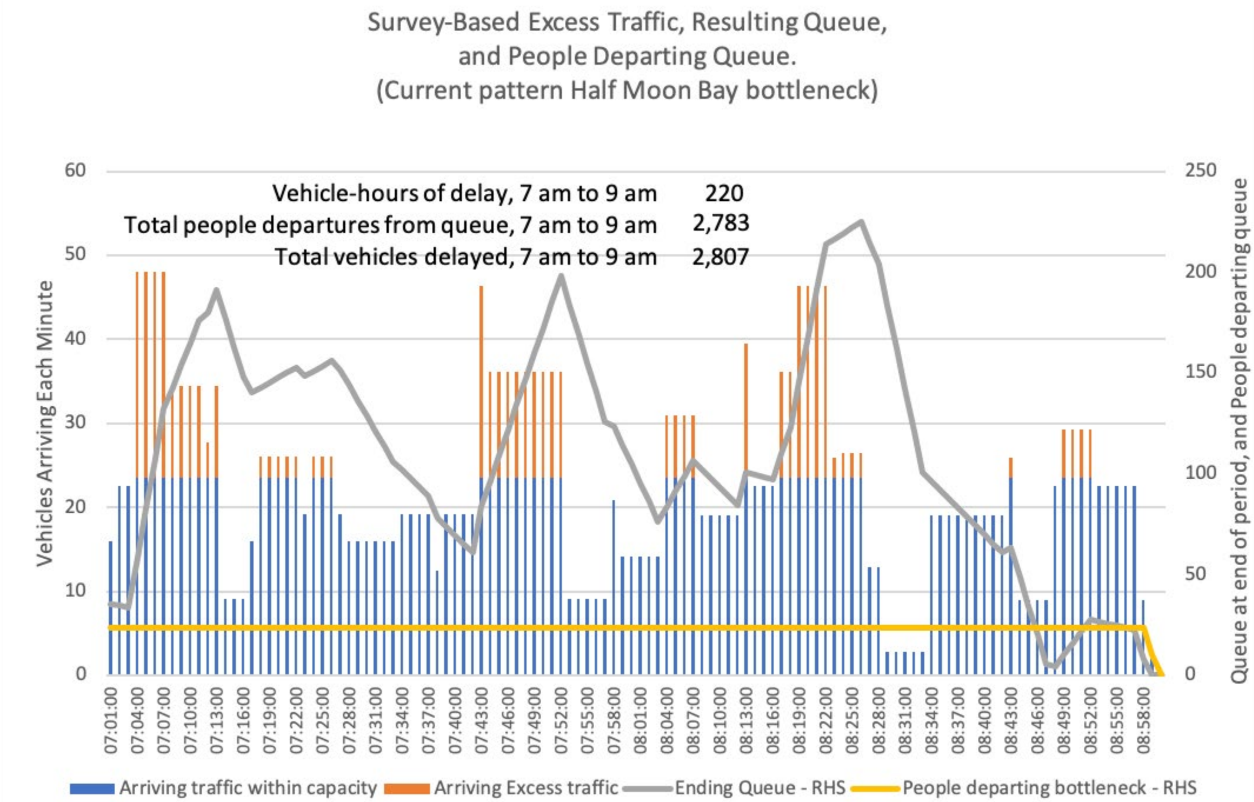


Figure 17. Current Traffic, Queue, and Delay, Half Moon Bay Bottleneck (modeled based on survey, Tuesday mornings)

STATISTICS

At the bottleneck, the model suggests that between 7 am and 9 am on typical Tuesdays, there are currently 514 excess vehicles, 315 in the first hour and 199 in the second, causing delay to over 2,800 vehicles and total delay of about 13,200 vehicle minutes (220 vehicle hours) of delay each typical Tuesday morning. The average delay per vehicle is just under 5 minutes, and the maximum delay is almost 10 minutes. See Table 14.

Table 14. Main Street/Highway 92 Bottleneck Queue Statistics (modeled)

		Proportion of Commuter Traffic in Period
Sum of excess 7 am to 9 am	514	21%
Sum of excess 7 am to 8 am	315	25%
Sum of excess 8 am to 9 am	199	17%
Vehicles delayed, 7 am to 9 am	2,807	
Total delay (minutes), 7 am to 9 am	13,213	
Average delay per vehicle (minutes)	4.7	
Maximum Queue 7 am to 9 am	225	
Maximum delay (minutes)	9.6	

Tuesdays were understood to be the worst day of the week for traffic at the bottleneck based on the Google Typical Traffic observations. Using the same historical data source that had been used for Table 4 (page 44), and comparing days of the week for the same 2017/2018 period and the same location, Table 15 was generated. It can be seen from Table 15 that Mondays have 8% less throughput than Tuesdays in the 7 am to 9 am peak period (last column, 92 is 8% less than 100). Wednesday traffic flows are about 86% of Tuesday traffic flows. Total delay and other statistics could be expected to be lower for these other days of the week compared with Tuesdays.

Table 15. Comparing Morning Traffic Flows by Day of Week (with Tuesday set to 100 for each time period)

Comparing Traffic Counts between days of the week, October 2017 to July 2018

	5-6 am	6-7 am	7-8 am	8-9 am	9-10 am	Total	7-9 am
Monday	89	91	93	91	92	91	92
Tuesday	100	100	100	100	100	100	100
Wednesday	89	87	85	87	89	87	86
Thursday	92	92	89	88	95	91	89
Friday	81	84	81	80	86	82	81

However, this expectation was thrown into doubt by some respondents in the survey who challenged the statement that Tuesdays were the worst days, and also by general statistics (beyond the case study route) that suggest that traffic builds through the week and is worst on Fridays.[73] Table 15 could be interpreted in a different way: in every time period each day of the week, fewer vehicles get through the bottleneck than on Tuesdays because traffic is worse than on Tuesdays. Thus far, the project team has been unable to reconcile the different sources. For the purposes of calculating benefits and costs for the case study, all five days have been treated as if they are the same as Tuesday.

As a first step in a pilot project for the route, the traffic will be measured with greater precision on the ground. In further applications of the method, it is recommended that actual count data be obtained of queue length and delay for all days of the week.

INTRA-PEAK DEMAND SHIFT, LATENT DEMAND, AND NEW TRAFFIC

Survey respondents had been asked at the beginning of the survey how much impact the bottleneck congestion had on them and what they do as a result. Figure 18 shows that 46% of respondents leave earlier than they would prefer (either to avoid the congestion or to allow enough time for it), while 37% leave later to avoid the congestion.

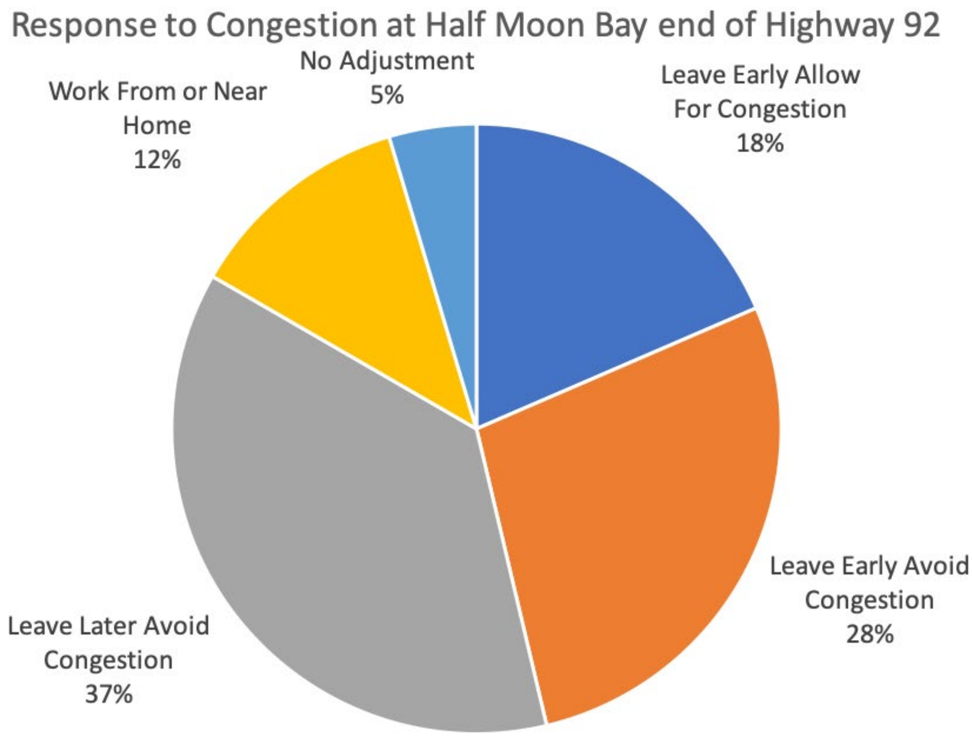


Figure 18. How People Adjust to the Congestion

Survey respondents were asked what they would do if the traffic congestion went away.

- If they currently do not travel, would they start to travel?
- If so, at what time would they leave home and by what mode?
- If they currently travel some of the time, would they increase the frequency, and would they change their time of travel or mode?
- If they currently travel every Tuesday, would they change their time of travel or mode?

Figure 19 shows the shape of the existing travel pattern (labeled 'current traffic') that causes the existing queue with the peak hour of travel (peak-of-the-peak) being 7:00 am to 8:00 am. The columns labeled 'current traffic no congestion' show that the peak-of-the-peak would shift to later (7:30 am to 8:30 am) if there were no congestion, and demand for travel in this later hour would be about 45% greater than the existing peak hour. This pattern could perhaps be anticipated and observed if the facility were (say) doubled in size.

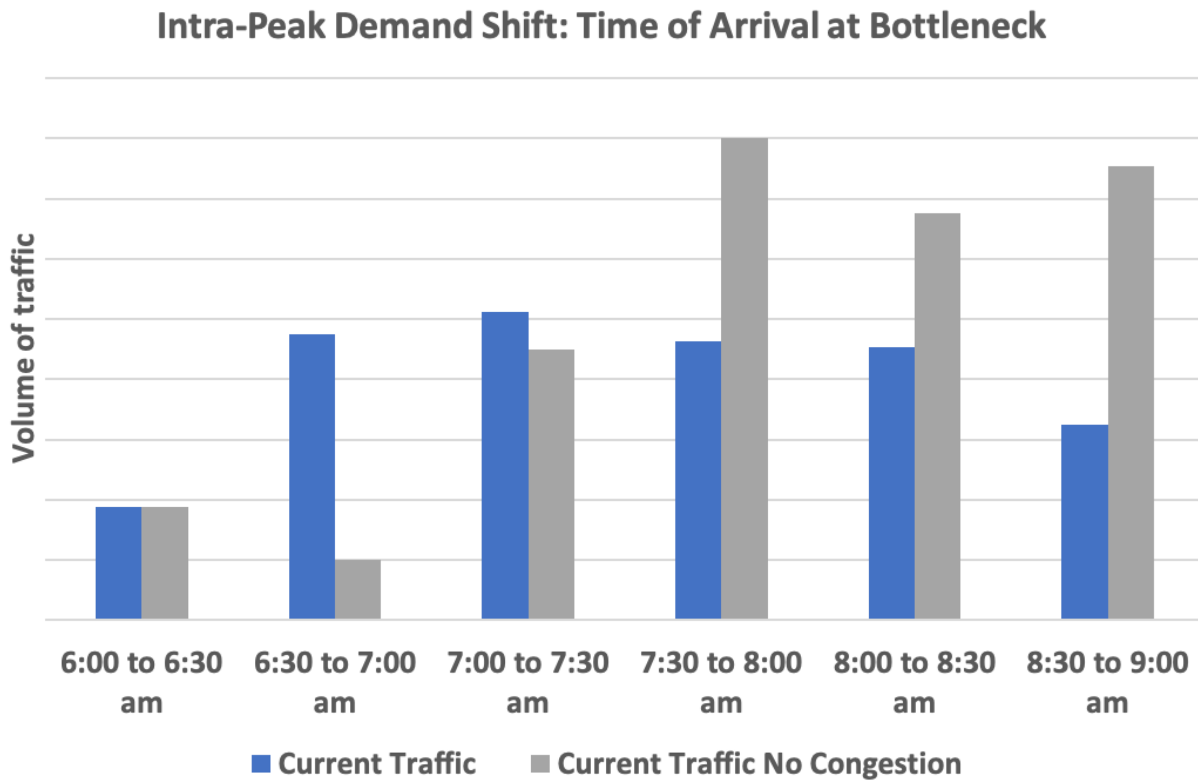


Figure 19. Trip-Time Shift if Congestion Removed (Intra-Peak Demand Shift)

As well as the time shift, there is also an increase in travel as existing travelers who are not traveling every Tuesday increase their trip frequency. These travelers account for a 14% increase in the overall traffic volume in the period from 5 am to 9 am: same people, more trips, which fits one of the definitions of suppressed demand.

To complete the picture, the removal of congestion would encourage people who do not currently travel to begin to travel. The estimated 5–9 am traffic would grow by a further 17% from this group. Figure 20 shows the result, with the shift from the blue existing traffic to the new total of the orange and grey.

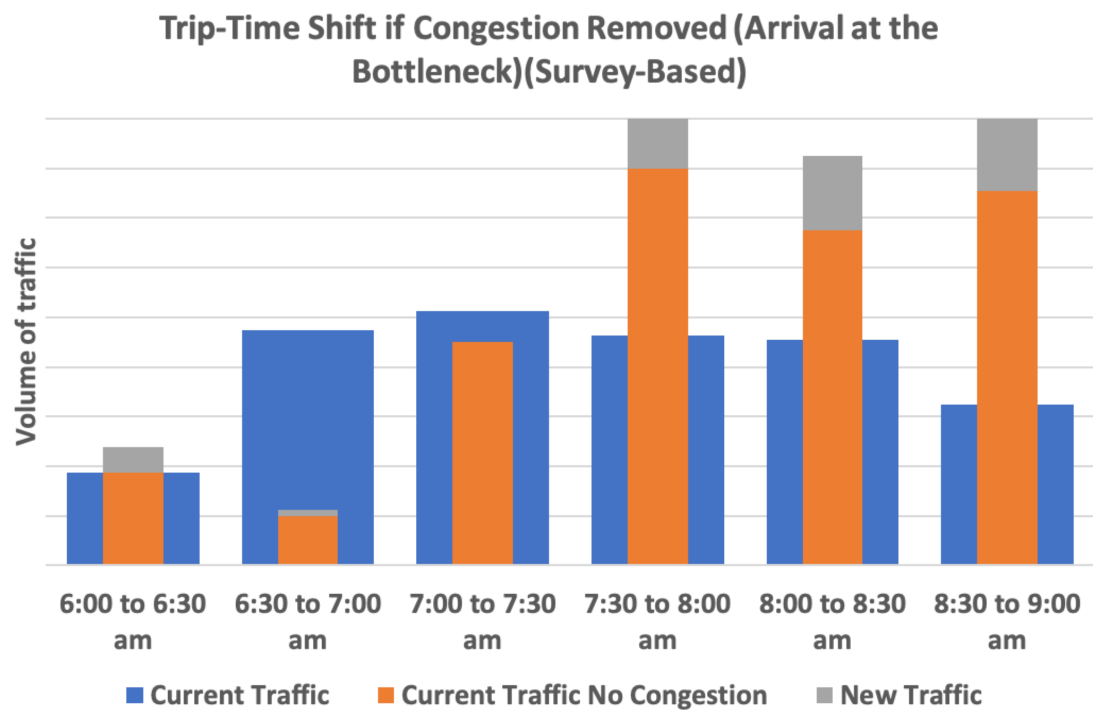


Figure 20. Intra-Peak Demand Shift Plus Suppressed Demand

A note of caution: the people who do not currently travel have been added at the same multiplier as each of the other respondents in the sample. There is no information that confirms (or argues with) an assumption that the survey response rate of people who do not currently travel during the 5 am to 9 am period is the same as that of those who do. However, analysis of the rating that this group of people gave for congestion's impact on them suggests to the project team that these people might have been more highly motivated to respond than regular users: they feel trapped by the congestion.

Surveying based on true random sampling of households would remove the above uncertainty.

The size of the intra-peak demand shift is significant. On a probability-adjusted basis, 3,716 people are commuters who currently pass through the bottleneck between 5 am and 9 am. Of these,

- 2,632 (71%) would shift to a later departure, for a total of 1,735 hours more time before leaving home, and
- 618 (17%) would shift to an earlier departure, for a total of 490 hours of earlier time at their destination.

In addition to this shift to more preferred departure times, current commuters would increase their trips in an amount that would be the same as if 508 additional people travelled regularly, and 627 people who are not currently travelling would begin to travel. In total, the initial 3,716 probability-adjusted travelers would increase to 4,851, an increase of 31%.

This analysis explains the mechanism by which the removal of congestion through any means could be followed by re-formed and larger queues.

TRAVELING AS A PASSENGER

The survey respondents were asked, while waiting and hoping for a change that makes the traffic congestion disappear, if they would help by traveling as a passenger in the interim, in a car, van, bus, or "shared Uber" style of transport. If saying no, they were asked whether, if there were a sufficient incentive payment available for doing so, they would change their answer. If further saying no, they were asked if they would provide rides for passengers. If further saying no, they were asked whether, if there were a sufficient payment available for doing so, they would provide rides for passengers for money. Through the mechanism of these four questions, respondents classified themselves into three major groups: people who would travel as passengers if the deal were right, people who only drive but would provide rides for people if the deal were right, and people who would only ever drive alone. See Figure 21 for the breakdown of Highway 92 commuters into these groups.

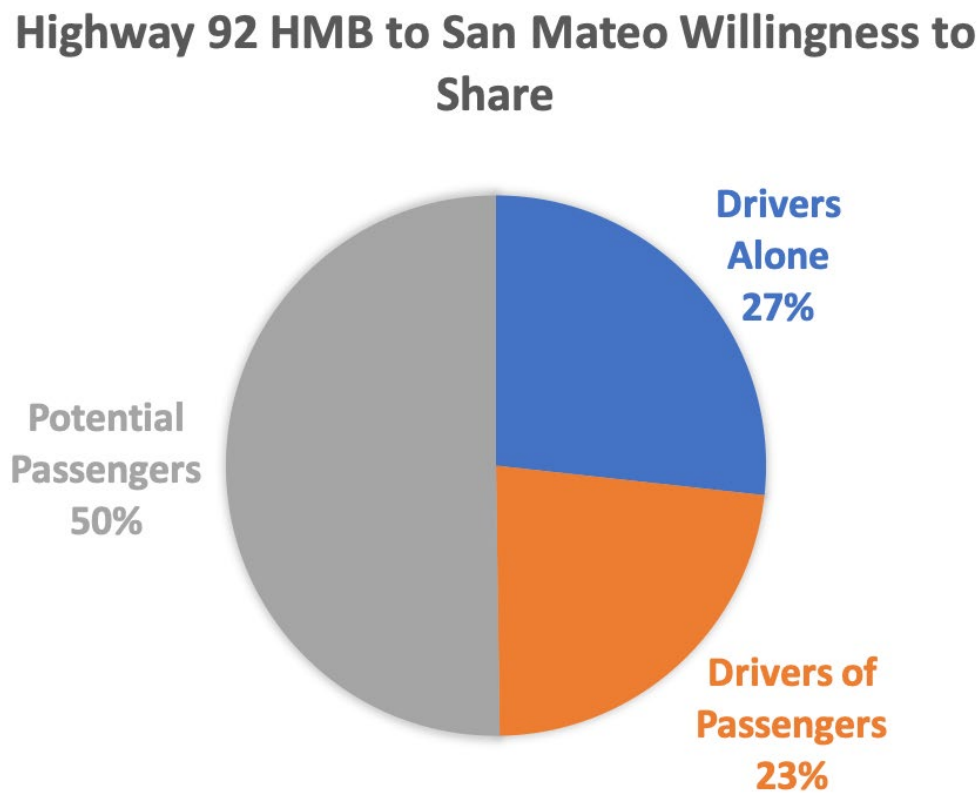


Figure 21. Willingness to Share (by Half Moon Bay Survey Respondents)

The proportions in Figure 21 suggest a limit on the potential traffic reduction from any passenger strategy on the corridor: the most that could be achieved would be a 50% reduction of traffic as the potential passengers who are currently driving shifted into vans or buses, or into the empty seats in the cars of drivers who would take passengers. If all passengers carpooled in the cars of people who would take passengers, the average occupancy of those cars would be 3.2 people per car (including the driver). The average occupancy of all commuter cars would be 2.0 people per car (including the driver). The average occupancy of the traffic, assuming 10% of the traffic is non-commuter with solo drivers, would be 1.9 people per vehicle.

Even if all the potential passengers shifted into buses and remaining cars were all single occupant vehicles (SOV), the maximum traffic reduction would be 50%.

REWARD CURVES

Having determined which respondents were willing to travel as passengers or to drive passengers, those respondents were then asked how much money they would need to receive to offset the effort involved in traveling as a passenger or driving passengers. The former group (potential passengers) were asked how much money they would need for traveling as a passenger in each of the following modes: a bus, a vanpool, a carpool, or a shared Uber. The latter group (potential drivers of passengers) were asked how much money they would need for providing a ride, on the basis it would be in the nature of a carpool arrangement. All were asked to assume it would be 'easy to do' and would not take any additional time.

The amounts provided were then stacked, for passengers, combining their lowest price option. The probability-adjusted number of travelers at each price level, cumulatively, were divided by the total probability-adjusted number of commuters. This calculation provided the reward curve that is shown in Figure 22.

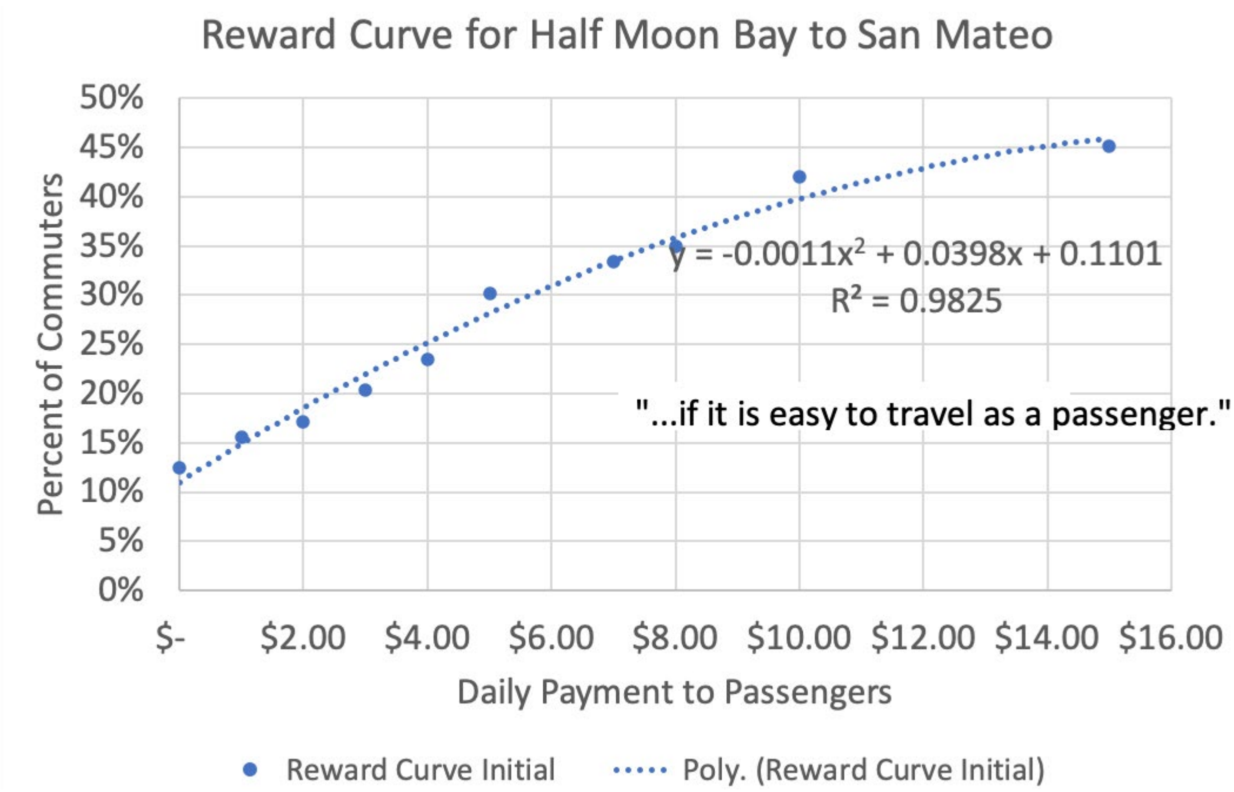


Figure 22. Reward Curve for Passengers: Half Moon Bay Current Commuters

It is important to note that the pre-condition on the price that respondents stated was that 'it is easy to travel as a passenger.' About 12.5% of the respondents indicated that if it was easy to travel as a passenger, they would do it for no payment. The highest rate of payment requested was $15. The regression line on the chart helps calculate the value of reward required to achieve a given level of commute trip reduction. With ease traveling as a passenger, a 30% reduction in commuter traffic could be achieved, according to this chart, for a daily payment to passengers of about $5.50. A 45% reduction would require a daily payment to passengers of $15.

Turning to the payments required by drivers who would take passengers, Figure 21 shows the 'price curve' for this group. Figure 21 had shown that 23% of commuters would only drive but would take passengers. Figure 23 shows that for this maximum level of passenger-taking, drivers would expect payment on the order of $15.

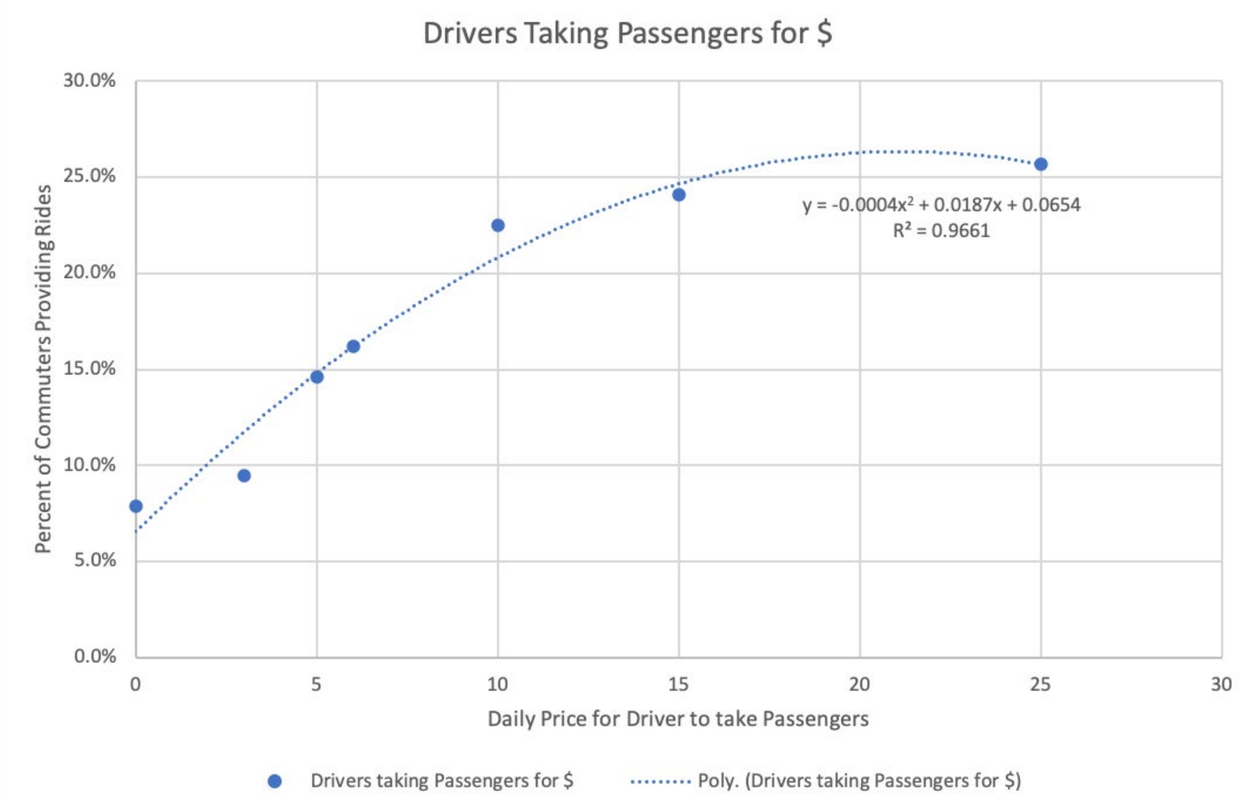


Figure 23. Price Curve for Drivers Taking Passengers, Half Moon Bay Commuters

A REWARD-FUELED SHIFT TO HIGH OCCUPANCY VEHICLES THROUGH THE BOTTLENECK

In order to develop the case study further, it was necessary to make some assumptions about the protocol that would be used to implement congestion-clearing payments to passengers on this route. It would be relatively easy to introduce a congestion-clearing payment and remove the current excess traffic on Tuesdays. About 600 people would need to be incentivized to switch (see Table 14 (page 61): 514 excess vehicles from 7 am to 9 am, plus a reasonable margin for variability). Other days of the week might require greater or lesser amounts. However, modeling of the reaction by travelers to the removal of the existing congestion revealed that the limit to traffic reduction (of 50% because 50% of the people say they will only drive), combined with the dramatic intra-peak demand shift, would result in the formation of new queues, albeit shorter ones, later in the peak period. Modeling the arrival of passengers and drivers based on the survey sample revealed an imbalance at peak such that sometimes the average occupancy of vehicles would need to exceed practical levels. It was realized that in order to prevent the re-formation of the bottleneck queue, the protocol would need to encourage people to continue traveling at less preferred times to dampen the impact of the intra-peak demand shift.

Three protocols were chosen and are discussed below as follows:

1. The first protocol: flexible carpooling, a meeting-place-based carpooling solution

2. The second protocol: going-early bonuses

3. The third protocol: mechanisms to limit the number of SOVs at peak

The first protocol: flexible carpooling, a meeting-place-based carpooling solution

The first protocol assumes that incentives will be offered at congestion-clearing levels and increased as congestion returns. Concurrently, a meeting-place-based carpooling solution ('flexible carpooling' from the literature review) is envisaged such that people arriving at the bottleneck intending to be passengers catch a ride with the next vehicle going to their destination. If there are no vehicles about to depart, all passengers for that destination combine in the vehicles of others who had arrived to be passengers to achieve quick departures, even though the traffic contributes to the formation of a queue. Figure 24 shows the results of this protocol.

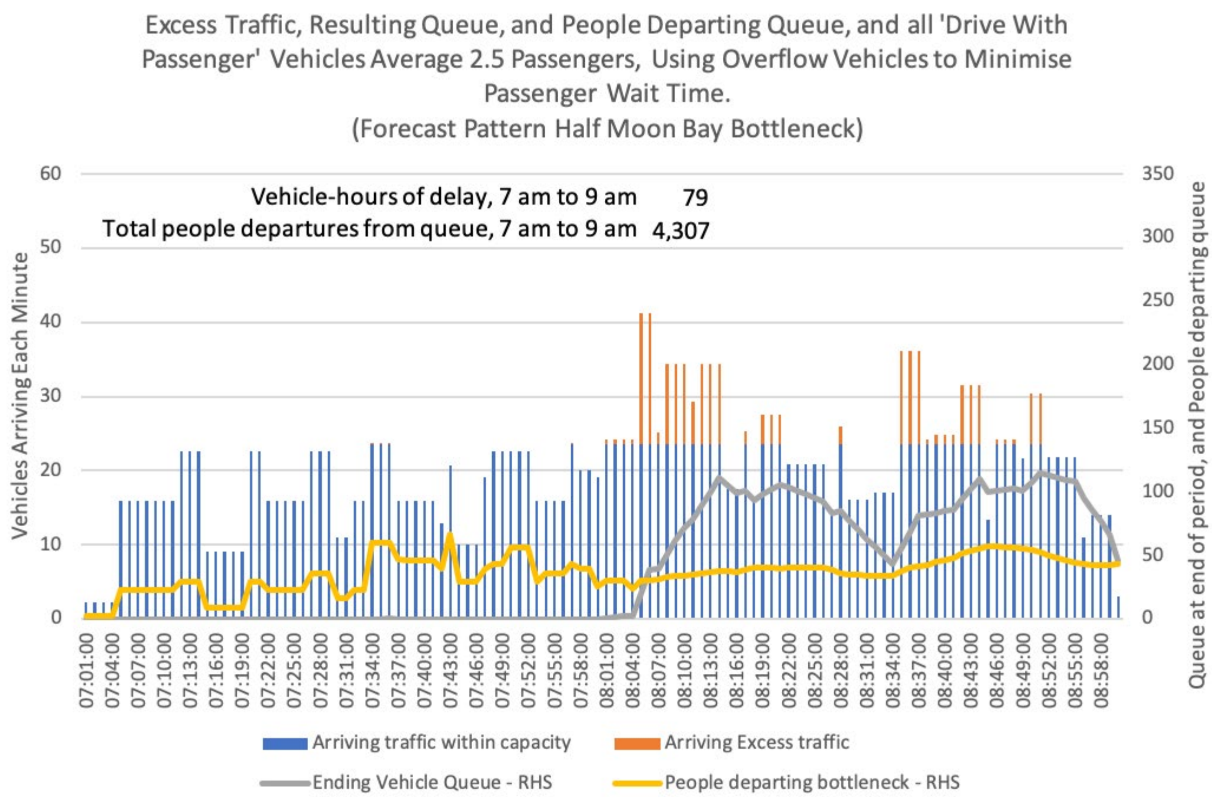


Figure 24. First Protocol Impact of Congestion-Clearing Payments to Passengers

Compared with the current situation shown in Figure 17 (page 60), the first modeled protocol would deliver a reduction in delay from 202 hours to 79 hours (a 61% reduction) and would increase the number of people traveling through the bottleneck from 2,783 to 4,308 (a 55% increase). The current queue that forms from 7 am or earlier would dissipate, but eventually a new queue would begin to form from about 8 am onwards as people shifted within the peak period to more preferred times of travel.

The value of payments to passengers associated with the first protocol is as follows, assuming all days of the week can be expected to be similar to the surveyed Tuesdays:

- Each day (excluding periods such as school holidays) approximately 1,900 passengers would be rewarded, representing 50% of the commuter traffic. Using the reward curve, it can be seen that the maximum reward on the curve ($15 per day) is expected to achieve no more than a 46% reduction. This difference (46% compared with 50%) is seen as being within the tolerances of a new solution. However, because the required number of passengers is expected to grow with population growth over the ensuing years, other work will be needed to ensure that a growing proportion of commuters can be reached.

- Once the full adjustment has been achieved (1,900 commuters traveling as passengers), the modeling suggests daily payments to deliver value to commuters in the order of $28,500 ($15 each). (Note that value can be delivered through prize draw entries at lower than the face value of the reward, so the cost is not expected to be at this level.)

- The initial situation will be less costly. The required reduction from 7 am to 9 am is 25% (600 people), which Figure 22 (page 66) suggests will require incentives worth $4 per day. The initial value transfer could be as low as $2,570 per day. For modeling purposes, the project team allowed a cost of $5 each for 514 passengers.

The project team has assumed that the actual cost of incentives will be 60% of their face value, on the expectation that passengers will take prize draw entries instead of cash in the appropriate proportions.

For modeling, it has therefore been calculated that the first year will start with a cost of $2,570 per day and end with a cost of $17,910 per day, with gradual growth to 1,990 passengers and adjustment of rates throughout the year. The daily value received by the participants would start at $4,200 and increase to $29,850 by the end of the first year.

However, under the first protocol, congestion will not be fully removed. It will be cleared from 7 am to 8 am, but a queue will form, as shown in Figure 24, from about 8 am each day.

The second protocol: going early bonuses

Analysis of the makeup of the traffic from 8 am to 9 am finds that there are 210 too many vehicles with 525 passengers, based on the first protocol, for the traffic to flow freely from 8 am to 9 am. The reason for this high level of demand is the intra-peak demand shift, in which people have said they will shift to their preferred time of travel. The question is, could those 210 drivers and 525 passengers be enticed to travel earlier (i.e. at a time that is not their preferred time of travel), or later, and if so, what would it cost? Are there other ways to solve the problem?

To solve this issue, a second protocol was chosen, in addition to the first protocol, to reward people for traveling in the new ‘pre-peak period’ of 7 am to 8 am by paying a bonus to passengers in that period. Because it is not desirable that all 210 vehicles travel in the last 15 minutes of the pre-peak period, the second protocol proposes a sliding scale that pays the highest bonus for traveling between 7:00 am and 7:15 am, a little less for traveling between 7:15 am and 7:30 am, a little less again for 7:30 am to 7:45 am, and the lowest bonus for 7:45 am to 8:00 am. Since this concept was not included in the survey, and to the best knowledge of the project team has not been done before, there is no information to rely on for estimating this cost. The project team needed to make an estimate.

For the purpose of modeling, $12 has been allowed as a bonus for the first 15 minutes (i.e., traveling an hour earlier than preference), $9 for the next, $6 for the next, and $3 for the final 15-minute period. This would be in addition to the passenger incentive and would be introduced gradually as the congestion rebuilds. Calibration will be required to find out whether these amounts are sufficient or excessive. The bonus has to be paid to all people who travel as passengers in each of the time periods covered. The total daily cost of the second protocol bonuses, by the end of the first year, is modeled to be $8,190.

With the second protocol in place, it is expected that congestion will be cleared. The combination of paying an incentive for traveling as a passenger and paying a bonus for traveling early provides a mechanism for modeling ongoing congestion-free travel. As population growth causes increased demand at the bottleneck, it can be removed by paying a bonus for earlier and earlier travel. Once the hour from 7 am to 8 am is full, a bonus can be added to entice people to travel in the 6:45 am to 7 am period. Once that period is full, the next earlier 15 minutes can be used, and so on. A similar bonus could be applied for ‘going later,’ but this strategy has not been modeled.

A third protocol: limiting SOV driving at peak

However, the modeling underlying these figures also finds that the peak period becomes decongested for the benefit of SOV drivers—those who would only drive, alone. As can be seen in Table 16, without a mechanism for preventing it (and such a mechanism has not been defined for the case study corridor), SOVs crowd out passenger-carrying vehicles, and passengers have to be incentivized to travel at ever earlier times to prevent a new queue forming.

Table 16. Passenger Volumes per 15-minute Period Over 20 Years

Passengers per 15-Minute Period at End of Each Year
Note 0 Passengers Means 100% SOV Demand in Period.
Note Assumption is that All Passengers are Incentivised,
Those Traveling Before 8 am Receive Going-Early Bonus

From	To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
8:45 AM	9:00 AM	290	278	266	254	242	228	214	200	186	172	154	140	122	106	88	70	52	34	12	0
8:30 AM	8:45 AM	242	228	216	202	186	172	154	140	124	106	88	70	50	32	12	0	0	0	0	0
8:15 AM	8:30 AM	280	268	256	242	230	218	202	188	172	160	142	126	108	92	72	48	4	0	0	0
8:00 AM	8:15 AM	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:45 AM	8:00 AM	428	416	386	360	330	298	262	230	198	160	124	88	46	6	0	0	0	0	0	0
7:30 AM	7:45 AM	490	486	480	474	470	464	458	452	446	438	432	426	418	414	366	316	266	176	76	0
7:15 AM	7:30 AM	326	316	306	294	282	272	258	246	234	220	206	192	178	162	148	128	114	96	78	28
7:00 AM	7:15 AM	86	234	390	392	384	376	366	356	348	336	328	318	306	296	284	272	260	248	234	224
6:45 AM	7:00 AM	0	0	0	156	328	444	436	432	424	418	410	402	394	386	376	368	360	350	342	330
6:30 AM	6:45 AM	0	0	0	0	0	60	264	456	588	586	584	582	580	578	574	572	570	568	566	564
6:15 AM	6:30 AM	0	0	0	0	0	0	0	0	68	284	506	582	580	578	574	572	570	568	566	564
6:00 AM	6:15 AM	0	0	0	0	0	0	0	0	0	0	0	146	390	578	574	572	570	568	566	564
5:45 AM	6:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	48	314	576	610	610	608	606
5:30 AM	5:45 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	232	508	608	606
5:15 AM	5:30 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	486
5:00 AM	5:15 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5:00 AM	9:00 AM	2157	2228	2303	2378	2457	2538	2621	2708	2797	2890	2985	3084	3185	3290	3397	3510	3625	3744	3867	3992

Note in Table 16 that the total number of passengers each year increases. The total of drivers (drive alone [SOV] and drive with passengers) increases by the same amount because 50% of the commuters are prepared to be passengers. The total traffic also increases by the growth in commercial traffic.

A third protocol is therefore required, to establish a mechanism to control or limit the number of SOVs traveling during the peak-of-the-peak. Limiting SOVs would make the projections more realistic in terms of the cost and likely success of incentives aiming to achieve the ongoing congestion-removal goal; it seems unlikely that passengers will travel at such early hours as are shown in Table 16. Ideas for such a mechanism include:

- The imposition of charges for SOVs during peak (which would provide funds to offset the costs of incentives, but would have all the challenges of implementing congestion pricing);
- A HOV bypass that gives HOVs priority access to the bottleneck and forces SOVs to queue, awaiting a space in the stream of HOVs;
- A solution that allows a fixed number of SOVs per minute.

The project team has not considered rewarding SOV drivers for traveling at earlier or later times, because this measure would be seen as encouraging SOV driving, which is counter to the intent of the solution.

A third protocol mechanism would be likely to reduce case study costs because more passengers would be able to travel in the preferred peak period of 8 am to 9 am. On the other hand, such a mechanism might incur costs related to the installation of control and access equipment.

Subsequent years

In subsequent years, forces of population and economic growth can be expected to result in increased need for rewards—both the number of people rewarded for traveling as passengers, and the rate at which they need to receive value for making or maintaining the shift to travelling at a less preferred time. The increase will also be compounded by any increase in non-commuter vehicles, to which a response will be required by compensating with an increase in commuter passenger numbers.

The project team has assumed the following:

- 3.27% annual growth in population, being the average rate of population growth ages 16+ for the catchment over the previous five years;
- 3% annual growth in non-commuter vehicles; and
- that 16% of the population wishes to commute between 7 am and 9 am.

On this basis the number of passengers the solution would need to compensate is modeled to grow at an average annual growth rate (year on year) of 4.47% over a twenty-year time horizon.

BENEFIT/COST CALCULATION

With costs of incentives calculated, and the amount of delay removed estimated, as well as the reduced vehicle trips, a total picture can emerge (see Table 17).

Twenty-year tables are included in Appendix 3 for each line item in the benefit-to-cost analysis, together with sensitivity analysis for key assumptions, which are described briefly in Table 18.

Overall, the solution, if implemented on the case study route, is estimated to create about half a billion dollars in net benefit over 20 years–in 2019 dollars discounted at 3%. The total benefits are $640 million and the total costs are $141 million. The ratio of benefit to cost (BCR) is 4.5. The solution is estimated to clear congestion at the bottleneck and keep it cleared. The project would also deliver 181,000 metric tons of CO_2-e greenhouse gas emission reductions over the 20-year period.

Table 17. Benefit/Cost Analysis for Congestion-Clearing Payments to Passengers, Half Moon Bay Bottleneck

Benefit/Cost Analysis for Congestion-Clearing Payments to Passengers, Highway 92							
			3%	7%	Emissions Impact (tonnes		
Costs	Year 1	Year 2	20 yr NPV at 3%	20 yr NPV at 7%	Year 1	Year 2	20 years total
Incentives for Passengers to travel as passengers	$ 2,048,000	$ 3,716,100	$ 70,760,835	$ 47,940,413			
Incentives for passengers to travel early as passengers	$ 122,850	$ 412,832	$ 29,465,204	$ 17,859,757			
Marketing	$ 100,000	$ 100,000	$ 2,473,465	$ 1,637,968			
Administration	$ 300,000	$ 300,000	$ 7,420,356	$ 4,913,874			
Bottleneck casual carpool parking	$ 16,143,809	$ 1,200,243	$ 30,883,899	$ 25,460,166			
Total Costs	$ 18,714,659	$ 5,729,175	$ 141,003,759	$ 97,812,178			
Benefits	Year 1	Year 2	20 yr NPV at 3%	20 yr NPV at 7%			
Reduced existing congestion costs							
Vehicle Delay Reduced (morning only)	$ 624,324	$ 1,286,108	$ 23,639,479	$ 16,063,088			
Vehicle Delay Reduced (evening)	$ 312,162	$ 643,054	$ 11,819,730	$ 8,031,541			
Fuel Use Reduced (adjusted for evening)	$ 59,058	$ 120,432	$ 2,106,186	$ 1,441,635			
Emissions/Pollution Reduced (adjusted for evening)	$ 6,975	$ 14,809	$ 304,026	$ 304,026	140	285	6,887
Reduced existing trip costs							
Vehicle Miles Travelled (fuel and maintenance)	$ 2,724,352	$ 4,492,352	$ 85,783,291	$ 58,186,922			
Emissions/Pollution	$ 198,542	$ 340,227	$ 7,680,057	$ 7,680,057	3,971	6,548	174,476
Destination Parking	$ 250,400	$ 412,900	$ 7,884,494	$ 5,348,063			
Congestion Beyond Corridor	$ 2,003,200	$ 3,303,200	$ 63,075,951	$ 42,784,501			
Crash Costs	$ 716,821	$ 1,180,183	$ 22,614,586	$ 15,337,838			
Total Benefits (traditional view)	$ 6,895,835	$ 11,793,265	$ 224,907,800	$ 155,177,671	4,110	6,833	181,362
Benefit:Cost Ratio	0.37	2.06	1.60	1.59			
Other quantified benefits							
Inconvenience Cost Reduced (morning only)	$ 5,004,129	$ 9,849,771	$ 111,946,582	$ 81,636,367			
Increased economic activity							
Incentive Multiplier Impact	$ 5,483,263	$ 9,394,980	$ 176,339,514	$ 119,826,514			
Expanded Income Impact	$ 1,773,000	$ 4,035,600	$ 126,626,962	$ 81,432,971			
Total Benefits (expanded view)	$ 19,156,226	$ 35,073,617	$ 639,820,858	$ 438,073,523			
Benefit:Cost Ratio (expanded view)	1.0	6.1	4.5	4.5			
Benefits exceed costs by			$ 498,817,099				

Table 18. Explanations for Each Line Item in the Benefit-to-Cost Analysis

Cost or Benefit Item	Description and Explanation
Incentives for commuters to travel as passengers	Based on the reward curve. The number of people needed to travel as passengers, to clear the congestion, is calculated after deduction of non-commuter traffic, with an assumption that 'going early' bonuses will reduce demand at preferred travel times. In this case study, perhaps because the bottleneck has been so long-standing, the maximum number of people prepared to travel as passengers must be incentivized to do so, and then all demand to travel as a passenger must be shifted to earlier and earlier travel times: see next section. The answer obtained for incentives is applied against a factor for the impact of prize draws, assuming the option will be available for participants to take an entry in the prize draw rather than taking the cash.
Bonus payments for going early	Passengers will be paid (or given prize draw entries) to shift away from their preferred travel time. This has yet to be tested for price with any commuters. It responds to the survey finding that too many drivers and passengers desire to travel in the peak-of-the-peak, causing the queue to re-form. Passengers will be paid greater amounts for each 15 minutes earlier that they travel, thereby spreading the peak demand. It is assumed that passengers will be paid this bonus and therefore will demand rides that people who will only drive will supply. The expectation is that a market for earlier rides will draw drivers from their preferred driving time. All people who travel as passengers in the earlier time period will receive the bonus, even if it is their preferred travel time. The number of people receiving the go early bonus is modeled by reference to the travel preferences of drive-alone people, assuming the remaining empty spaces will be filled by vehicles with passengers. These are modeled for each year-end number of commuters, commercial vehicles, and passengers, and the mid-point is estimated.
Marketing	An allowance for the cost of telling people about the program. It is expected to be relatively easy to communicate, and it is further expected that there will be signage at the bottleneck, and a high level of interest from people who would like the congestion reduced. There might also have been a lot of public discussion about the solution while it was being approved as a budget item. It is also assumed that the main way of communicating changes to the incentives or bonuses will be by SMS or inside the App. The model allows a reasonable amount for the first year, when there will be costs of getting started, but the total incentives will be low. The same amount is allowed for the second year when the total incentives paid out will be greater. Thereafter, the annual amount increments by the growth of the total incentives over the previous year. In the model the cost of marketing is 2.42% of the total incentives paid out.
Administration	The allowance for the cost of operating the solution is calculated in the same way as for the marketing, above. The allowance for administration includes an assumption of detailed monitoring and ongoing research and reporting of the impact of the solution. Administration works out to 7.3% of the total incentives paid out.

Cost or Benefit Item	Description and Explanation
Bottleneck flexible carpool parking	The first protocol calls for meeting-place-based carpool formation. It may be necessary to provide a 'park and pool' facility that can be used, such that people can drive to the bottleneck, leave their car as they form fuller cars with others, and collect the car on the return journey. For a conservative projection, costs for such a facility have been assumed and modeled to be incurred as the number of passengers grows over the years. The number of car parking spaces has been set at 75% of the number of passengers. There are potential alternatives to this cost. Least cost would be to find that creating a thicker market for passenger trips would deliver carpool formation apps that work effectively. Another alternative could be to provide frequent shuttles during the peak periods from the residential communities to the bottleneck and back. Such shuttles would probably have to run on 10-minute frequencies to be successful. A daily charge for parking has not been included, though one could be introduced to encourage efficient use of space provided. Finally, no residual value has been recognized for the facilities at the end of twenty years, even though such a value would exist.
Vehicle delay reduced	This number is the amount of time experienced by the people who are delayed by the current traffic congestion. The total delay is calculated for the traffic based on survey results (though an on-the-ground metric would be preferable and should be used when available). Total hours of delay are incremented each year based on an assumption of growth. In the absence of the solution, delay would be increasing due to population growth. The total hours of delay are applied to a rate per hour and total days to give an annual cost. Delay is assumed for the return journey to be 50% of the morning delay reduction. This estimate is an arbitrary assumption because the project team has not focused on evening delay. The delay so calculated is applied against a value of time for private citizens and a value of time for commercial travelers on a weighted average basis.
Fuel use reduced	This metric is an estimate of the amount of fuel used by vehicles idling while being delayed at the bottleneck. There is an allowance made for vehicles that have stop–start technology, with an assumption that these reduce fuel consumption. The assumption in the model is that fuel is used on a per time basis rather than a per mile basis while being delayed.
Emissions reduced	The amount of fuel-use reduced is converted to an amount of CO_2-e (in metric tons) and applied against a per metric ton rate for these emissions. The rate is incremented in the model by the rate of the Socialized Cost of Carbon referred to by U.S. DOT for calculating benefit-to-cost ratios.
Vehicle miles traveled	The solution successfully implemented will result in approximately half of all commuters traveling as passengers instead of as drivers. For modeling purposes, it is assumed these passengers will drive to the bottleneck and will leave their cars near the bottleneck for the day. Therefore, the reduction in VMT will be the number of passenger trips (morning only) times the round-trip distance each day from the bottleneck to the destination and back. The model uses the average round trip distance found from the survey. The model applies the total miles reduced against a cost per mile for fuel and maintenance to arrive at an annual savings amount. The modeling assumes the annual savings amount will grow over time as the number of passenger trips increases. If the model should instead only take account of existing trips avoided (ignoring growth), the present value of 20-year benefits discounted at 3% would be reduced by $90 million.
Emissions/Pollution from reduced VMT	An average vehicle efficiency rate is used to calculate the fuel portion of the above fuel and maintenance cost, and the amount of fuel not burned is modeled to deliver a reduction in emissions. This reduction is valued in the same way as the delay reduction emissions above.

Cost or Benefit Item	Description and Explanation
Destination parking	The vast majority of people passing the bottleneck do not pay for parking at their destination. But someone pays for the parking provided—the employer or the local government, for example. An allowance is made for an avoided parking cost at a fixed average rate per day, times the number of passenger trips. The expectation is that in the face of a reduction in traffic based on the solution, there would be a reduction in demand for parking at the various destinations, and the reduced amount of parking would benefit either the passenger (if paying for parking) or the business or other entity providing ‘free’ parking. The value in the base case is $1 per space per day.
Congestion beyond the corridor	The case study is focused on the costs and benefits of removing congestion at the bottleneck. It is expected that there is a benefit to all the other traffic in the region if these vehicles are not on the roads of the region. C/CAG of San Mateo County has previously run a program in which they paid $8 per vehicle-round-trip avoided for people who carpooled. The model assumes that the County will value the reduction in regional traffic from this solution in the same way. The rate per vehicle-round-trip-avoided is applied to the total passenger trips taken each year.
Crash costs	The quantity of crashes, both minor and major, is considered to be a product of the distance traveled and the probability of different intensity crashes. The cost of such crashes, including a value of lives lost in fatal crashes, is a standard component of benefit cost analysis. The project team used the method outlined in U.S. DOT guidance to calculate the crash costs avoided and used a California crash rate statistical set to predict the rate of crashes.[74]
Inconvenience cost reduced	The traffic congestion at the bottleneck causes people to travel at less preferred times than they otherwise would. The survey gathered information about the change in times that people would travel, given a congestion-free option. Some people would shift to traveling later, some to traveling earlier. As a benefit, this shift reflects greater time at home, or greater time at work, both of which can be valued as an important benefit. In the model, it is assumed that the initial change benefits all travelers (drivers and passengers) as the congestion is removed, and the benefit is reduced by the proportion of people who are estimated to be traveling earlier to receive a bonus. Each year the proportion of the original benefit that still applies is calculated. It is applied against the same value of travel time factor used for commuters to value the reduction of delay.
Multiplier impact	In an ongoing implementation of this solution, the participants are expected to gain disposable income through the working of the solution—income that would most likely be spent in the local economy. It is expected that the funds for ongoing operations will be provided by the local people in some way, except for the regional benefit, which should be provided from regional funds. All the cash benefits are summed, and the cash costs deducted, and the result, assumed to be added purchasing power, is assigned a multiplier of 1.25, meaning that for each additional dollar in the commuter’s hands, the local economy will gain a further $1.25.
Expanded income impact	As a result of the removal of congestion, survey respondents indicated that they would start traveling to work past the bottleneck. Their earnings would represent an increase in funds available to people in the Coastside to carry out economic activity. The dollar amount is calculated based on the value of an hour of earnings each day.

Cost or Benefit Item	Description and Explanation
Opportunity impact	As well as the actual new income earned, the removal of congestion at the bottleneck would also give all residents a greater level of opportunity to earn more money, get more education, or shop in different locations. This new level of opportunity should have some value in the benefit-to-cost analysis. However, this impact has not been valued in the benefit-to-cost analysis due to the complexity involved and lack of existing methodology.
Wellbeing impact	Researchers in the UK found that the wellbeing from a reduced delay of 20 minutes in the daily commute was the same as receiving a 19% increase in pay. All current commuters will experience a reduction in delay of about this amount. However, this impact has not been valued in the benefit-to-cost analysis.
Emissions impact	The amount of CO_2-e in metric tons has been calculated for each of the emissions reduction line items.

Figure 25 provides information about how the level of incentives change over time. Total incentives estimated for year 1 are $2.2 million, rising to $4.1 million in year 2, $6.7 million by year 10, and $12.1 million by year 20 (all in 2019 dollars). The project team expects that there would be many opportunities to reduce this cost by positive engagement with the people who travel through the bottleneck.

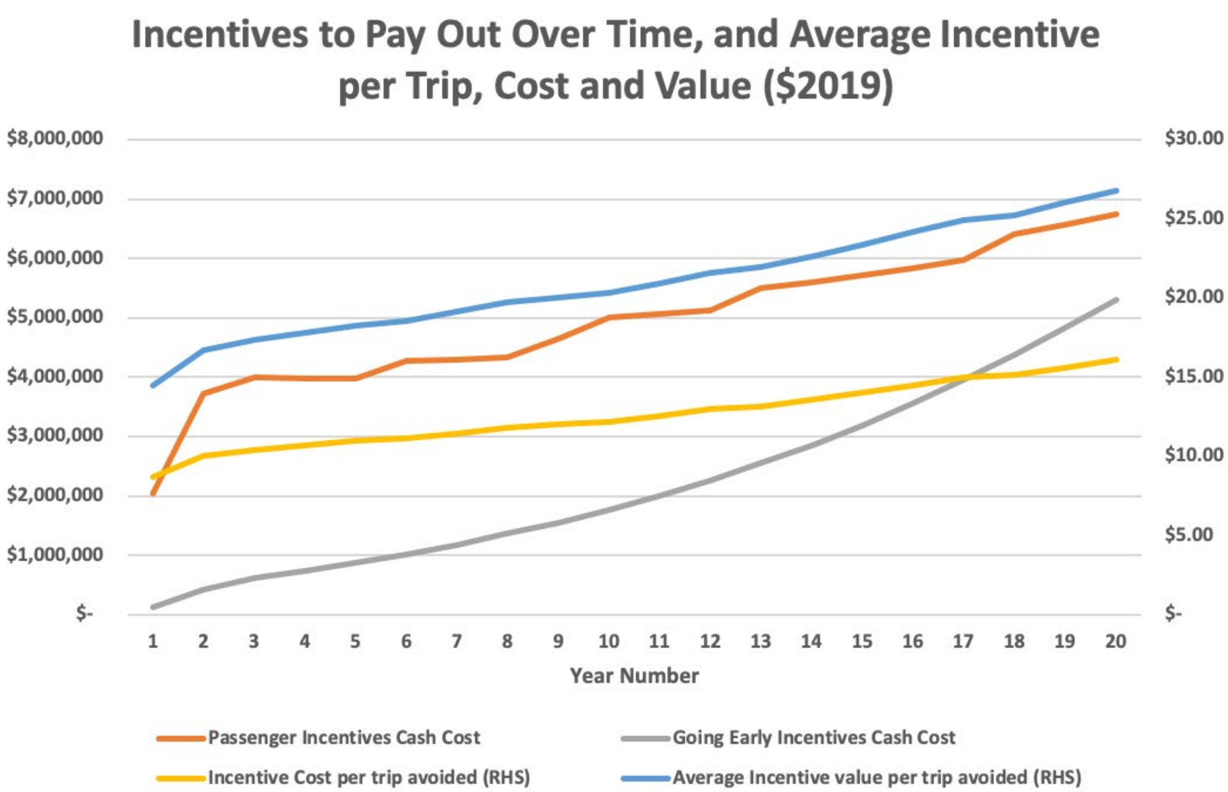


Figure 25. Incentive Cost Per Trip and In Total

Sensitivity analysis

The project team wanted to assess the likely impact of variation in the major assumptions underlying the benefit cost analysis. Table 19 shows the calculation of an adjustment of 5% to key assumptions. Each line item stands alone; no cumulative effect has been calculated.

The factors are ranked in the order of the impact on the present value of 20-year costs.

The factor with the largest impact, where a 5% increase in the factor brings a $9.3 million increase in costs, is the proportion of the population who would commute between 7 am and 9 am. A 5% increase would also bring a big increase in the total benefits ($17.2 million). The combination of these impacts (adding $9.3 million in costs and adding $17.2 million in benefits) reduces the overall benefit to cost ratio from 4.5 to 4.4. This factor also includes people who are not already using the route, who would begin to use the route if congestion were cleared. To maintain free flow, every additional person would have to travel as a passenger: hence the cost increase. At the same time, every additional person would be accruing benefits that would have value: low-cost trip-making, vehicle trips avoided, and income that would grow the local economy.

Conversely, but for the same reasons each 5% reduction in the assumed rate of population growth would reduce costs by $4.1 million.

Reducing the drive-alone rate by 5% would reduce costs by about $5 million, as would reducing the number of days people are incentivized and increasing the departure rate from the bottleneck.

Table 19. Sensitivity Analysis (adjusting each key factor by 5%)

Factor	Base Case Value	New Value	Change	PV 20-yr Costs in $2019 at 3% discount rate, $million	Change from Base Case Costs, $million	PV 20-yr Benefits in $2019 at 3% discount rate, $million	Change from Base Case Benefits, $million	PV 20-yr BCR	Change from Base Case BCR
Base Case				$ 141.0		$ 639.8		4.5	
Proportion of population who commute	15.46%	16.23%	4.98%	$ 150.3	$ 9.3	$ 657.0	$ 17.2	4.4	-0.1
Required rate of incentives based on the reward curve, per passenger day	$ 15.00	15.75	5.00%	$ 144.4	$ 3.4	$ 639.9	$ 0.1	4.4	-0.1
Cost savings from passengers taking lottery entries instead of cash (value is expected average discount to value perceived by passengers)	40%	38%	-5.00%	$ 144.3	$ 3.3	$ 639.8	$ -	4.4	-0.1
Required go-early bonus per hour prorated	$ 12.00	$ 12.60	5.00%	$ 142.6	$ 1.6	$ 639.7	$ (0.1)	4.5	0
Value of time for commuters	$ 25.00	$ 23.75	-5.00%	$ 141.0	$ -	$ 632.8	$ (7.0)	4.5	0
Growth in non-commuter traffic	3%	3.15%	5.00%	$ 141.0	$ -	$ 638.6	$ (1.2)	4.5	0
Starting level of people to switch to being passengers	514	540	5.06%	$ 141.0	$ -	$ 639.9	$ 0.1	4.5	0
Current level of delay in minutes per day	13,213	13,874	5.00%	$ 141.0	$ -	$ 641.8	$ 2.0	4.6	0.1
Starting level of non-commuter traffic	271	285	5.17%	$ 140.7	$ (0.3)	$ 635.3	$ (4.5)	4.5	0
Rate of population growth	3.27%	3.11%	-4.89%	$ 136.9	$ (4.1)	$ 630.8	$ (9.0)	4.6	0.1
Drive alone percent of total commuters	25%	23.75%	-5.00%	$ 136.1	$ (4.9)	$ 642.1	$ 2.3	4.7	0.2
Number of days per year passengers are incentivized	200	190	-5.00%	$ 136.0	$ (5.0)	$ 613.6	$ (26.2)	4.5	0
Rate of bottleneck departure in vehicles per hour	1,300	1,365	5.00%	$ 135.9	$ (5.1)	$ 637.3	$ (2.5)	4.7	0.2

Reducing the drive-alone rate would also increase the total benefits. Combining the reduction in cost and the increase in benefits, the drive-alone rate is the most valuable factor to adjust on the basis of impact on the benefit to cost ratio. The second most valuable factor is increasing the rate of departure from the bottleneck.

If greater levels of incentives were required per passenger, a 5% greater switching incentive would add $3.4 million to total costs, while a 5% greater go-early bonus would add $1.6 million. Many of the factors assessed deliver no change to the total costs and only small changes to the value of benefits at a sensitivity adjustment of 5%.

In addition to the 5% variation, the project team wished to identify the impact of variability in factors the team was less confident about. The factor for which the project team has the least confidence is the go-early bonus because this reward has not been previously tested and was discovered as a requirement after the survey had been completed. If it took twice as much to incentivize this shift, on a per hour basis, from $12 to $24, the impact on 20-year costs would be $31.2 million ($2019), and the BCR would fall to 3.7.

The factor in the model that the project team feels is most likely understated is the value of the benefit of reduced need for destination parking. This change has been incorporated into the model at a value of $1 per space per day, which is considered to be very low. At a more realistic $4 per day, the 20-year benefits would increase by $23.7 million ($2019), and the BCR would rise to 4.7.

ADJUSTING FOR SELF-SELECTION BIAS IN THE SAMPLE

The use of the voter database was a compromise to seek randomness at a cost that was within the budget for the research project.

Finding that 80% of adult residents are in the voter database, and that email and phone contact details were available, the voter records were judged to be an appropriate avenue for obtaining a representative sample.

The project team used several methods to satisfy themselves that the sample was in fact representative.

The age distribution of the sample, the household income distribution, and the education achievement distribution were sufficiently similar to the general population that it seemed a representative sample had been achieved. However, once the multiplier was determined (see below), it became clear that there was significant self-selection by people who use Highway 92 or are interested in doing so. Put another way, there was significant non-participation by people who do not use Highway 92 or are not interested in doing so, even though the invitation email asked for everyone's input.

While each respondent who might currently be seen in Tuesday morning traffic was calculated to represent about 67 people, each respondent who would not be seen in the traffic would have to represent about 865 people.

The survey found three groups of people: those who are currently in the traffic; those who would join the traffic if congestion were removed; and those who would not be in the traffic under any circumstances. The question to be answered is as follows: which multiplier should be used for the middle group: those who would be in the traffic if the congestion were removed? In the modeling for the project, the middle group has been assigned a multiplier equal to the first group, a judgment call. The project team became comfortable with this decision based on the analysis in Table 20.

Table 20. Impact Scores for Different Response Groups

Code	Description	Impact	N
Y	Avg impact for Ys	72.71154	52
S	Avg Impact for Ss	69.26923	26
N	Avg impact for Ns	63.66667	42
NY	Avg impact for NYs	78.14286	7
NS	Avg impact for NSs	72.94737	19
NN	Avg impact for NNs	46.3125	16

Table 20 shows the average score that different groups of respondents assigned to the impact that the congestion has on them. Respondents could choose an impact from 0–100, where 0 was ‘not much impact at all’ and 100 was ‘the congestion has a very large impact on my decision about how and when to use this route.’ The table shows the simple average of these ratings by the groups subsequently determined by responses to later questions.

The codes (groups) are as follows:

Y = yes, I travel every Tuesday;

S = I travel some Tuesdays;

N = I do not travel on Tuesdays;

NY = I do not travel on Tuesdays but would regularly if congestion went away;

NS = I do not travel on Tuesdays but would sometimes if congestion went away; and

NN = I do not travel on Tuesdays and would not travel on Tuesdays even if congestion went away.

What is interesting here is the average scores of the NYs and NSs. The impact they perceive the congestion has on them is higher than that perceived by any of the other groups.

Comparing the desire to respond to the survey (self-selection bias) of the different groups, it would be suggested that NN people would be least interested (they imagine change on the route having little impact on them), consistent with a low average impact score. It is suggested that NY and NS people, on the other hand, would be most interested (change on the route might have a big impact on them, allowing them to seek work, or education, that they perceive as unavailable because of the congestion), consistent with a high average impact score. The Y and YS people are already making trips and so understand the congestion (though they are interested in it improving), so they have a mid-level average impact score.

On the basis of the above discussion, it could be argued that the multiplier for the NY and NS group (people who would start to travel if congestion were tamed) should be lower than for the Y and YS group because they are more likely to self-select based on the impact score. Because there is no way to estimate the size of the actual population who would be NY and NS, the project team decided to use the multiplier that had been calculated for the Y and YS people.

In order to avoid the problem of self-selection bias, the project team recommends that future projects carry out a survey of a true random sample of the catchment for the target route as an important first step in the pilot project to test the protocols developed herein.

In this regard, the team had rejected an internet-based panel survey provider as a supplier to gather the project sample on the basis that such a supplier would not be able to sufficiently reach the users of the target route–because early in the project this group was expected to be the target of the survey. This decision could be revisited on the basis that the eventual survey specification was for a representative sample of all residents, rather than users of the route. Only about 8% of Coastside residents 16+ years of age are users of the case study route during the peak morning hours of 7 am to 9 am. An internet-based panel survey provider may be able to deliver a sample of residents without the self-selection bias.

VI. DISCUSSION

The objective of the project was to develop a Method for estimating the costs and benefits of congestion-clearing payments to passengers that could be repeated for many different locations. As described, a draft Method was documented, and a case study developed. The draft Method was followed for the case study, but where necessary it was modified or departed from. A benefit-to-cost analysis has been completed.

The objective of the whole project was to conceptualize congestion-clearing payments to passengers as a real alternative, in order to establish a method for estimating the costs and benefits that would support its inclusion in decision-making processes for resolving traffic congestion if in fact such inclusion is warranted. In the absence of such a method, the alternative of CCPTP would never be seriously considered against other options for solving congestion. The litmus test for the Method is whether it can deliver information that truly supports such decision-making. The development of the method is just a first step, because it is highly probable that an actual implementation would unfold differently from the estimates. Hence, a sub-objective has been to create an 'order of magnitude' estimate to help decide whether to carry out pilot projects that could be used to establish the reliability of the Method.

There were advantages and disadvantages to the route chosen for the case study. On the one hand, the Coastside community is relatively affluent and has an extremely low share of passenger travel (except for driving students to school). There are almost no transit users and almost no carpoolers, so there is no existing culture of traveling as a passenger. Commuters travel to a relatively high number of different destinations. On the other hand, the route is relatively simple to understand: there is a single catchment; no existing advantages for HOV travel; and the vast majority of commuters have a large part of the route in common.

The following discussion highlights the key lessons learned from the combined development of the Method and the case study.

ESTIMATING THE VOLUME OF TRAFFIC TO BE REMOVED

Current excess traffic

It was originally envisaged that existing traffic flow data could be used to calculate the excess traffic, but lack of data about the length of the queue made this approach impossible. Instead, the project team calculated the excess traffic using a spreadsheet model based on the survey responses. The proportions of traffic in the model for each hour were compared with actual historical counts and found to be reasonable. However, it would be much more reliable to have actual data about the ebb and flow of the queue. Such reliable data would also provide an informational basis for ongoing management of congestion at the bottleneck.

A new implementation of technology may be called for, for capturing and communicating reliable data about queue formation and dissipation.

An allowance was made that 10% of the current traffic is non-commuter traffic. This proportion is an educated estimate based on discussion with the Half Moon Bay City Traffic Engineer and should be based on better data in the future.

Queue length analysis

Google Maps Typical Traffic and Google Maps Live Traffic were used to identify the periods of bad congestion and to estimate the maximum length of the queue, but while low-cost and easily available, these online sources are not highly reliable, and the algorithms used by Google for calculating typical traffic are not available. Traffic estimated from the spreadsheet model was compared with traffic from Google and found to be reasonable. However, anecdotal descriptions of the traffic at this bottleneck paint a much worse picture than either Maps or the spreadsheet model describe. The project team was unable to resolve this discrepancy. Future projects should gather much more detailed information about the actual traffic on the ground. Future projects in other areas might also have better existing traffic count data, and or data available from commercial providers of traffic data based on probes or smart-phone tracking.

Suppressed demand

The survey provided a method for estimating increased use by existing travelers and new use by non-travelers. There is an issue with the multiplier for non-travelers who would start to use the route if congestion went away, and it is possible this quantity is over- or under-stated. This problem will be resolved with a better sampling technique, as described earlier.

The most significant lesson learned in the project is the strength of the intra-peak demand shift. Having observed it from the survey for Highway 92, the project team suggests that it provides a generalizable explanation for how congestion behaves. It is predictable and obvious, but it has not been described in a minute-by-minute way before. Once congestion is removed, people's travel times can be expected to drift towards their preferred travel time, and most people seem to prefer a similar travel time. In the case study, 88% of people would change their departure time if congestion went away.

The implication of this intra-peak demand shift insight for the CCPTP concept—and it probably holds across most long-standing bottleneck locations—would be that within the first year it would be necessary to get every person willing to be a passenger to make the switch, so the solution would almost immediately gravitate to the highest level of incentive and a significant go-early bonus.

Induced traffic

No information was found upon which to base assumptions of non-commuter traffic growth, partly because there is no information about the current amount of non-commuter traffic. There is historical information about population growth in the catchment, and the modeling has assumed the recent growth rate of 3.27% per year will be maintained. The spreadsheet model shows modest increases in costs if the 3% growth rate for non-commuter traffic is raised, even as high as 5%. It is thought by the project team that the bottleneck has constrained economic growth in the catchment, so these assumptions (3.27% and 3%) could be low—they are the growth that is assumed to already exist, rather than growth that a free-flowing highway could generate.

The challenge for the case study route is that the majority of the impact of current congestion is experienced by the City of Half Moon Bay, which has some ability to manage its growth rate. However, the catchment also includes all of the Coastside, and there were no reports of intentions to manage population growth in the rest of the catchment outside the City of Half Moon Bay. While the City has limited its growth over the past five years to just 2% per year (against a target of 1%), the catchment itself has grown by 3.27%.

Traffic volume to remove

Two spreadsheet models were developed. The first converted the survey data into minute-by-minute traffic flows and queues for both the current traffic and the traffic after removing congestion. The second spreadsheet modeled the changes to the traffic over twenty years. The combination of the two spreadsheets delivered volumes of people required to travel as passengers, each year, to keep traffic at free-flowing levels, supported by a myriad of assumptions about a dynamic system that is challenging to predict. It is in part challenging to predict (and therefore somewhat unreliable) because the CCPTP solution has not been attempted before, so there is no track record of how the system will respond.

INCENTIVES

Reward curves and go-early bonus

The case study catchment is a relatively affluent area with higher than average household incomes compared to other parts of the state and country. The project team's expectation is that because the population is affluent, their propensity to travel as passengers will be lower than for less affluent areas, and the deal for traveling as a passenger would have to be better to attract a similar number of passengers. Therefore, the team expects that the overall cost of the solution for the case-study route would be higher than would likely be the case for a corridor involving a less affluent area.

The reward curve for traveling as a passenger was created and bears a strong resemblance to the one from Comsis, even giving similar amounts in 2019 dollars: see Figure 26. Note that the 'new reward curve' represents the combination of the people who are already traveling plus the new people who would start to travel if congestion was defeated. The number of people to convert to passengers sits at the very highest level of the reward curve. The go-early bonus is in addition to the reward curve and was one of the key lessons learned from the project. Note that there could equally be a go-later bonus for passengers to travel later than the peak-of-the-peak, and this bonus would work in the same fashion. For simplicity, the modeling has been limited to go-early.

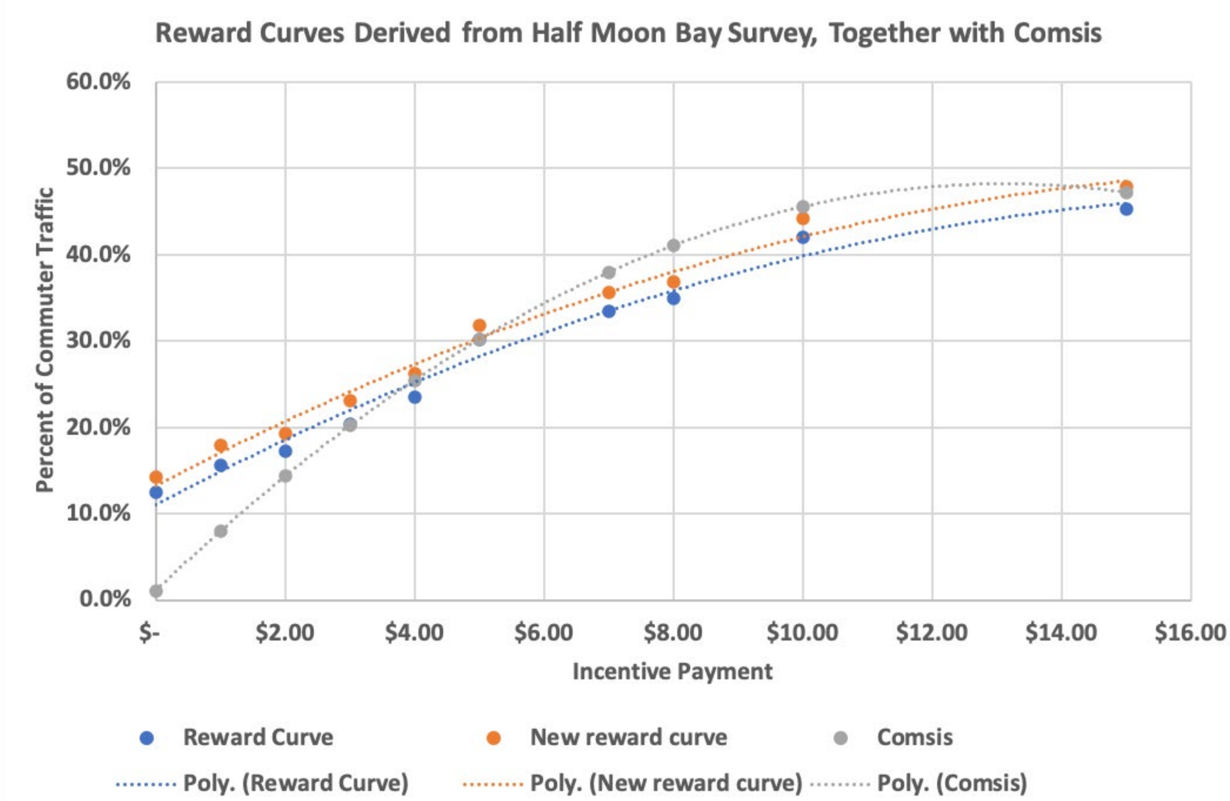


Figure 26. Reward Curves with Comsis for Comparison

The annual cost of the go-early bonus grows to a high level, and it would incentivize passengers as early as 5:15 am, with many 15-minute periods at the peak of the peak of solely SOV traffic, if there is no limit on SOV traffic. However, as shown in Table 21, if the proportion of drivers who would only drive alone were reduced from 25% of commuters to 20% of commuters (more in line with the project team's expectations), the number of 15-minute periods of solely SOV traffic would be much lower (than shown in Table 16 (page 71)). Also, the 20-year cost would be reduced by $17 million.

Table 21. Passengers Per 15 Minutes (if drive alone proportion is 20% of commuters)

Passengers per 15-Minute Period at End of Each Year
Note 0 Passengers Means 100% SOV Demand in Period.
Note Assumption is that All Passengers are Incentivised,
Those Traveling Before 8 am Receive Going-Early Bonus

From	To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
8:45 AM	9:00 AM	348	338	328	318	308	298	284	274	262	250	236	224	208	194	180	166	148	134	116	100
8:30 AM	8:45 AM	310	300	288	276	264	252	238	224	212	198	182	166	152	136	118	102	84	68	48	26
8:15 AM	8:30 AM	340	330	320	310	300	288	276	264	250	240	224	212	196	184	166	152	136	120	104	86
8:00 AM	8:15 AM	128	112	96	78	58	40	18	0	0	0	0	0	0	0	0	0	0	0	0	0
7:45 AM	8:00 AM	458	452	444	438	434	426	418	410	382	352	322	292	256	224	190	154	118	78	38	0
7:30 AM	7:45 AM	140	248	364	480	490	486	478	472	470	462	456	452	444	440	430	422	418	412	402	396
7:15 AM	7:30 AM	0	0	0	0	108	236	320	310	298	286	276	264	252	240	226	212	198	182	168	154
7:00 AM	7:15 AM	0	0	0	0	0	0	60	206	356	380	374	366	354	346	336	326	316	306	294	284
6:45 AM	7:00 AM	0	0	0	0	0	0	0	0	0	136	308	436	432	424	416	408	402	394	386	378
6:30 AM	6:45 AM	0	0	0	0	0	0	0	0	0	0	0	44	244	432	574	572	570	568	566	564
6:15 AM	6:30 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	280	496	568	566	564
6:00 AM	6:15 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	390	564
5:45 AM	6:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62
5:30 AM	5:45 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5:15 AM	5:30 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5:00 AM	5:15 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5:00 AM	9:00 AM	1725	1782	1843	1904	1967	2032	2099	2168	2239	2314	2389	2468	2551	2634	2721	2810	2903	2998	3097	3198

Incentive structure options

The case study survey did not explore the detail of incentive structure options. The addition of the go-early bonus is tentative in terms of the amount required, because this option was not surveyed. A further survey is recommended to test ideas for structures and to inform the go-early bonus to fine-tune a pilot implementation in due course.

THE NEED FOR BOTTLENECK PARKING AND LIMITS ON SOV TRAVEL

The project team had not anticipated the magnitude of the switch to being passengers required for congestion clearing in the case study corridor. In order to make this particular project work, it was identified that parking would be required near the bottleneck for fast formation of fuller vehicles to common destinations, while combining travelers from multiple origin communities. Also, there would need to be some limit on SOV travel so that vehicles carrying passengers would be able to access the route without the queue re-forming. The team had anticipated a lower number of passengers required, and therefore the need for transactions with a smaller proportion of the traffic, than has turned out to be the case for this corridor. One argument put forth in favor of incentives rather than tolls was that incentives required transactions with far fewer people. However, in the case study, there would be incentive transactions with 50% of the commuters each day and trip-recording activity by 75% of commuters (drivers with passengers, and passengers).

Limits on SOV travel could operate through tolls, HOV bypass, SOV flow restriction, or another method to be determined. If it operated through tolls, the revenue from the tolls could be a source of funds for the CCPTP solution.

SOURCE OF FUNDS

It is possible that existing funding mechanisms would not provide ongoing funding for a CCPTP solution. On the basis that the beneficiaries of a solution should fund the solution, it may be that an implementation on the case study corridor should be funded in part by the Coastside residents, and in part by the region that benefits from fewer vehicles arriving from the Coastside (as valued in the benefit/cost analysis, including destination parking, congestion beyond the corridor, and crash costs as set out in Tables 17 and 18, from page 73). It is likely that Coastside property values would increase as a result of the benefits from the solution, justifying residents providing some contribution towards the costs of the solution, perhaps through property taxation. The project team notes that existing legislation might constrain the use of property tax funds and might require new legislation or the passage of a referendum (or both) to make that source of funds available.

Because of the risks inherent in implementing a new solution, however, and the potential for the benefit of the lessons learned to flow to a much wider national and international community, the project team envisages that a pilot project to prove the concept would not require funding from residents.

PILOT PROJECT RECOMMENDATION

The project team recommends that a pilot project be carried out on the case study route as a means of calibrating the lessons learned from the project. It is highly likely that the reward curve derived in the project will be different when the solution is implemented. The following are considerations for the design of the pilot project:

1. Develop project with community and commuter involvement in line with commons governance best practices;

2. A period of funding that encourages long-term culture change (5 years for example);

3. Random sample survey to confirm findings and estimates from the project survey;

4. Monitor traffic and queues daily to build case and confirm estimates;

5. Survey for structure of incentives and size of go-early bonus;

6. Explore and confirm mechanism for limiting SOVs during peak.

COMMONS GOVERNANCE

As discussed in the literature, Ostrom proposed eight principles for successful governance of the commons. The proposed solution is evaluated against these principles in Table 22.

Table 22. Evaluation of Solution Through a Commons Governance Lens

Principle	Discussion
Define clear group boundaries	The roadways are quite well defined, the bottleneck is easy to describe, and the times of heavy use are well established and can be monitored. The users of the highway during the morning peak are quite easy to define in groups, including commuters, commercial travelers, and freight.
Match rules governing use of the common goods to local needs and conditions	The envisaged rules would appear to fit local circumstances; however, the assumed compatibility needs to be checked. In particular, the idea of putting limits on SOV travel during peak-of-the-peak is expected to require buy-in to succeed.
Ensure that those affected by the rules can participate in modifying the rules	Moving the concept forward should involve the local community and users of the bottleneck, and ideally, they would collectively be given the right to set rules for use during the morning peak.
Make sure the rule-making rights of community members are respected by outside authorities	The reality is that the users of the highway control how well the highway works. The implementation should involve tacit agreement by outside authorities (Caltrans for the case study route?) that the users have the right to set rules for use during the morning peak.
Develop a system, carried out by community members, for monitoring members' behavior	The technology exists to build a monitoring system that knows when people travel as passengers and computes the daily impact of the solution.
Use graduated sanctions for rule violators	The immediate sanction is the opportunity cost of traveling as a passenger and being rewarded, versus traveling alone and not being rewarded. On some basis, the community should decide if they want to pay incentives and make other relevant rules to resolve the bottleneck, such as HOV bypass, or scheduling for SOVs. The design of sanctions would be up to the community as they design the rules.
Provide accessible, low-cost means for dispute resolution	It is hoped that the incentive structure itself helps to avoid disputes; however, it is possible that it will raise new ones that the solution has not yet identified.
Build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system	The catchment of each bottleneck should have responsibility for managing its use of the bottleneck. Some users might be in the catchment of more than one bottleneck. The entire interconnected system is the transportation system.

A NEW PARADIGM FOR LAND USE REGULATION

If congestion could be tamed, economic development that had previously been suppressed could emerge, to the detriment of the new situation. It might be necessary to update land use regulations and other local rules to reflect the new environment. For example, consider jurisdictions where approval of a new use for a parcel of land is contingent on the impact that the project will have on the level of traffic and developers have to make financial contributions to offset their added traffic impact. The traffic mitigation rules may need to be changed to require developers to fund passenger payment incentives needed to absorb the new trips into existing vehicles.

UNADDRESSED QUESTIONS/LIMITATIONS

Destination convergence

The case study commuter population travels to as many as twenty major and twenty minor destinations around Silicon Valley. It is not possible to model and draw conclusions about destination convergence based on the small sample size obtained in the survey. The project team expects that, with about 3,000 commuters in total traveling to these various destinations, there will be sufficient opportunity for shared journeys without unrealistic effort by those involved. However, while a multiplier was used to gross up the population traveling in each time period, no similar multiplier was available to inform adjusting the population by time period and destination. Because everyone using the corridor passes through the bottleneck, it is as if they have the same origin, so people from diverse residential areas can join together for artificial density to any one destination. What is not known is the amount of effort it will take on the part of commuters to achieve the target level of passenger trips.

Single corridor, multiple bottlenecks

The Method anticipated analyzing a corridor that might have extensive congestion and multiple potential bottlenecks. The case study analyzed a single bottleneck in a corridor without needing to consider the impact of downstream bottlenecks. As a result, the case study does not provide an example of the process by which multiple bottlenecks might be analyzed and how they might impact each other. This process has therefore not been developed beyond the discussion in the Current Excess Traffic section of this report.

Technological ubiquity

Over 80% of Americans use a smartphone.[75] However, the project did not assess the ubiquity of smart phones in the catchment, nor the extent of their use by potential passengers. For this catchment with above-average household income, the project team expects almost ubiquitous access to smart phones and the internet. For other catchments it would be a valid survey question. The CCPTP solution relies on smart phones for its effectiveness–both for capturing instances of passenger travel and for communication within the system (advising potential participants of the current offers)–so rather than establishing work-arounds it is more likely that an implementation would find a way to enable access to smart phones for those who wanted to participate but did not have the technology. In case accommodations are needed for non-smart-phone users, there are models for other app-based systems that could be instructive here.[76]

Safety

Safety was raised as a concern in the focus groups, but no questions were asked in the survey about the issue of safety. The project team made a conscious choice here. The assumption made was that people who would not travel as a passenger due to safety concerns would not indicate a willingness to be a passenger in the survey, so would be part of the commuter group who would continue to drive. Safety is, of course, an important consideration, and the CCPTP solution is not likely to succeed in an environment that lacks sufficient safety considerations. The app anticipated for the CCPTP solution is not an app that commuters would use to arrange rides, with strangers or otherwise. It would be an app for recognizing and rewarding travel as a passenger. Commuters would use other mechanisms to arrange their passenger trips. If carpooling, they might use a commercially available app, and would rely on the safety mechanisms built into that app. They also might arrange rides with known neighbors or co-workers. Under the protocols set out above, they might join a carpool at a meeting-place near the bottleneck. The use of the CCPTP rewarding App would capture information about who is driving and who is riding. The safety rules that apply to Casual Carpooling, discussed in the literature, would apply here also: that there should always be two or more passengers for each driver; and that anyone lining up for a meeting-place-based carpool can always step back and let someone else go first if they do not like the look of a vehicle or driver. Casual carpooling has operated for decades without serious safety issues, and without technology for capturing details of who is traveling in which vehicle.

Return journeys and trip chaining

The project has also been silent on a key issue associated with traveling as a passenger: the return journey. Traditional carpooling is a round-trip concept, while a flexible carpool trip is clearly a one-way facilitation. Is there a risk that some incentivized morning passengers might have trouble arranging their return journey? If so, what proportion? What can be done to help? Would it change the cost and benefit calculations?

Further, the complexity of modern commute patterns involving for example childcare and after school pick-ups and drop offs, other household errands, or multiple employment locations, might further exacerbate the difficulty for people to travel as passengers[77,78] Is it possible some people could just be unable to travel as passengers in spite of a willingness to do so?

The answers to these questions are not yet known. The underlying idea is that if the ‘deal’ is right, the participants, or potential participants, will figure out how to solve such issues. The solution will be creating a thick market (one with many buyers) for people prepared to (and funded to) travel as a passenger in both directions each day. It seems likely that the market would respond with mechanisms that resolve the issue. Some people will arrange traditional carpools; others might find an appropriate meeting place at the morning destination end of the corridor to facilitate carpools or other shared modes for the return journey at very low cost. Guaranteed ride home (GRH) might provide a fallback position to help resolve these issues.

The cost of alternative solutions

Using typical cost per lane mile data from FHWA, inflated to 2019 dollars, the project team has calculated that the cost of doubling the capacity of the 11-mile stretch of Highway 92 that is the focus of the case study (adding a lane each way) would be between $71.5 million and $369.1 million depending on whether the existing lanes needed to be improved, and which sections qualified as ‘rolling’ versus ‘mountainous.’[79] Such an expansion could be expected to take several years, if indeed approval could be achieved. Once developed, such an expanded facility could be expected to ‘fill up’ again with congestion within five years. It would certainly be congested again within a year, based on the calculations for the case study. If evaluated on equivalent assumptions to the case study benefit-to-cost analysis, the project team expects that the total benefits would also be much lower for highway expansion than for the congestion-clearing alternative. Table 23 compares the impacts of the two alternatives of doubling infrastructure capacity and implementing congestion-clearing payments to passengers across the range of factors included in the benefit cost analysis.

Table 23. Comparison of Impacts of Building Infrastructure vs Congestion-Clearing Payments to Passengers

Factor	Double Infrastructure Capacity	CCPTP
Cost	$71–$369 Million plus annual outgoings	$143 million
Delay	Reduce but not eliminate, builds up again over time	Eliminate
VMT	No change, or increase due to expanded capacity	Large reduction that is sustained over time
Crash costs	Increase with increased VMT	Reductions with VMT
Fuel-use and emissions	Increase with increased VMT, reduce with reduced delay	Reductions with VMT, reductions with eliminated delay
Destination parking	Increase with build-up of trips over time	Reduce with reduction of trips
Congestion beyond the corridor	Increase with build-up of trips over time	Reduction and maintained reduction over time
Inconvenience cost for traveling at less preferred times	Reduced with increased capacity, but over time reverts and impacts more people	Reduced with removal of congestion, and offset by going-early payments
Incentive multiplier impact	Some job creation during construction will have equivalent impact in the short term	Ongoing impact as incentive is distributed in community
Expanded income impact	Some improvement as delays are reduced, but reducing over time	Ongoing impact as congestion is kept under control

It is noted that Caltrans has no plans in the pipeline to expand the Highway 92 facility.

Commons governance mechanics

The project has not designed a commons governance process for making the decision to implement CCPTP, nor the setting of local rules. The project team anticipates arranging funding for one or more pilot routes. In a commons governance sense, the local community would be given the opportunity to accept an apparently generous offer, in which they would receive a significant flow of incentives into their community in return for changing how they travel and agreeing to some limits on SOV travel at peak-of-peak. Commons governance experts will be consulted to ensure optimal processes are developed and adopted.

COMPLEMENTARY MITIGATIONS

In the introduction, there was a reference to decarbonization of transport. CCPTP is a very expensive method for achieving this end (at an average cost of almost $800 per metric ton of carbon dioxide emissions avoided on the case study route). However, as a co-benefit of a project with a decongestion goal, it is worthwhile. What might be more valuable for the solution is that the drive to avoid climate change might make the 'deal' less costly in future than the estimates in the case study if commuters become oriented to seeking less carbon-intensive solutions for everyday life activities such as commuting to work.

The survey avoided invoking thoughts of climate change when asking people whether they would travel as a passenger, and for what amount of money. It was feared that invoking this important societal issue would muddy the thought process. However, in the absence of other significant emission reduction opportunities, it seems plausible to suggest that many potential passengers and drivers would put some carbon emission reduction value on participation, thereby reducing the total incentives required to achieve the congestion-reduction goal.

Consistent with the above, the idea of electric carpools is also worthy of consideration. As electric vehicles penetrate the Coastside market, variable incentives could be used to encourage electric vehicle drivers to use their vehicles to provide rides for passengers in the CCPTP solution, adding to the emissions reduction benefits of the pilot project.

GENERALIZABILITY

The foregoing results for the case study route are not intended to be generalizable to other routes or corridors. The results give an impression of how valuable a CCPTP implementation could be, but without undertaking a similar amount of analysis for other routes it would be dangerous to make any assumptions for other locations based on the case study route. It is possible that after a number of locations have been carefully surveyed and analysed some rules of thumb might emerge, but the project team advises caution.

It is likely that some conclusions could be made that are generalizable. The project team proposes the following list:

- The concept of intra-peak demand shift, in which a large proportion of commuters are traveling at an earlier of later time than they would prefer and given the removal of congestion would shift to more preferred departure times and cause the queue to reform. That 88% of case study participants shift to later or earlier departure is not expected to be generalizable to other routes.

- The need for a concept such as the go-early bonus to offset the intra-peak demand shift in order to keep congestion away.

- The concept of segmentation of commuters into three groups as follows: those who would only drive, alone; those who would only drive but would provide rides; and those who are prepared to be passengers. That 27% of case study participants would categorize into the only drive, alone, segment is not expected to be generalizable to other routes.

- The concept of a reward curve for people to switch to being passengers, in which greater levels of reward attract greater levels of people to being passengers. That the required reward for 47% of case study participants to switch is $15 per trip is not expected to be generalizable to other routes.

- The concept of calculating a BCR for a CCPTP solution, in which 20 years of benefits and 20 years of costs are calculated, discounted to the present, and compared. That the result for the case study route was a BCR of 4.5 is not expected to be generalizable to other routes.

VII. CONCLUSIONS

This report has described the methodology for route-by-route evaluation of an idea that could potentially have dramatic impacts on transportation as it is experienced around the world. The passenger-payments project at the Mineta Transportation Institute could be the first step in a revolution.

Analysis of a challenging case study route provides a positive community return on the costs of providing congestion-clearing payments to passengers. The present value of 20 years of costs, discounted at 3%, falls within the range of estimated costs of expanding the facility, and the benefits of ongoing congestion-relief are likely much greater than for facility expansion.

THE REVISED METHOD

The project team developed a draft Method and then applied it to a case study route in order to refine the Method. The revised method is now summarized in six steps as shown in Figure 27.

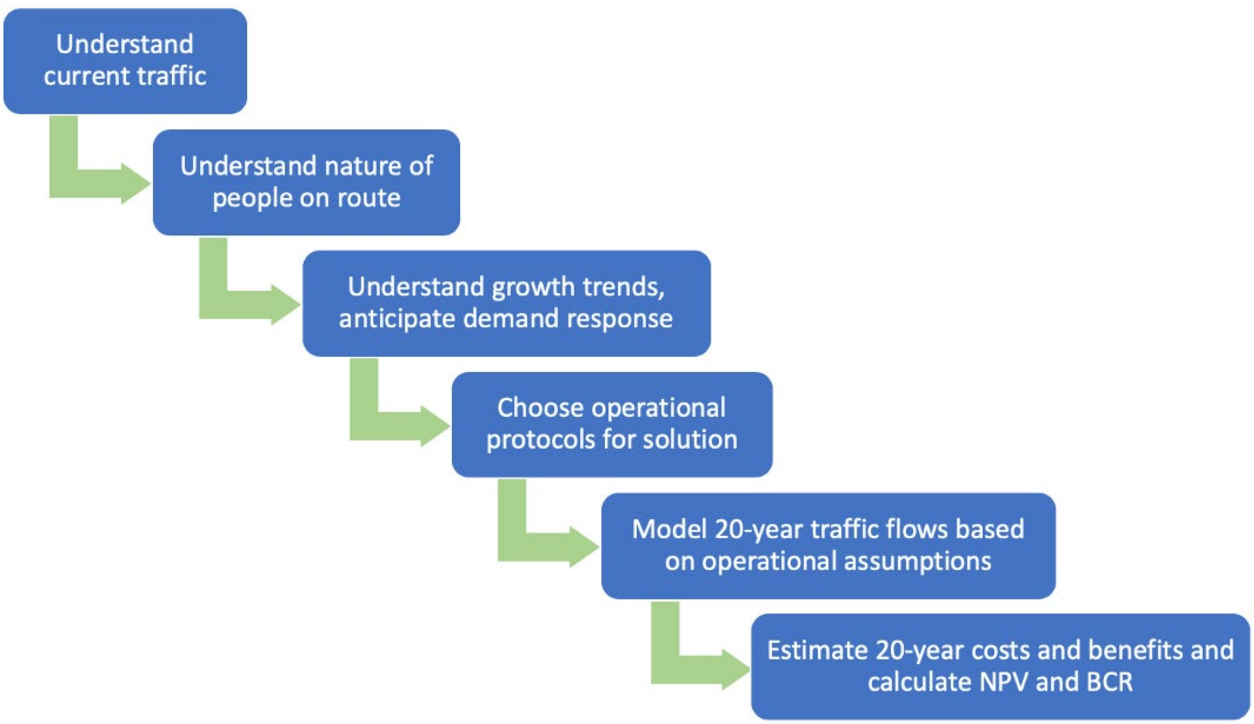


Figure 27. Revised Method

A number of aspects of the draft Method were modified or discarded. Table 24 lists methodological thoughts and insights that may be useful for future research to further develop the CCPTP solution concept.

Table 24. Methodological Thoughts After Applying Method to Case Study Route

Step	Methodological thoughts and insights
Understand current traffic	Corridor definition is required, including identification of consecutive bottlenecks. The case study evaluated a single bottleneck. Consecutive bottlenecks in a corridor will necessitate more complex modeling. If the corridor has parallel routes, data will be needed for all routes. The case study evaluated a route that did not have parallel routes. Parallel routes in a corridor will necessitate more complex modeling because removing congestion on one route will attract traffic from the parallel route. Existing traffic flow data are not sufficiently precise for queue and excess traffic measurement and new sources or protocols should be developed. New data collection about queue formation on a minute by minute basis would facilitate analysis and management of the queue for each bottleneck. A representative catchment survey can provide useful data about the current traffic. Real counts of the split between commuter and non-commuter traffic are necessary, as are vehicle occupancy rates, destinations, presence and utilization of public transport through the bottleneck, downstream congestion and existing initiatives in place to limit it, and parking prices at the destinations. Validate traffic flow calculations based on the survey with actual traffic counts.
Understand nature of people on route	A true random sample of residents in the catchment for the corridor will deliver the most reliable information about existing use and likely future use absent the congestion. An online survey panel that delivers random selection within a defined catchment might provide a sufficiently representative sample as a lower cost alternative to a true random sample. This alternative should be tested. The SurveyMonkey survey instrument used in the project is available for replication on other routes. The survey should be used to determine existing use, propensity to travel as a passenger for money or not, and propensity, if not a potential passenger, to provide rides for money or not, if for money how much, to calculate a reward curve for the route. The case study assumed a 'go early bonus' but did not survey to find out how much this incentive would need to be. Future surveys should investigate the concept of the go-early bonus as a mechanism for responding to intra-peak demand shift.
Understand growth trends, anticipate demand response	Survey to determine how departure times, frequency of travel, and travel by those not currently using the route would change absent the congestion. If parallel routes exist, survey and model for route-change reactions. Consider whether existing population and economic growth trends would change if there were no congestion. Note that this might be highly subjective if the corridor under consideration is sub-regional and if population and economic growth data is not available for sub-regions.

Step	Methodological thoughts and insights
Choose operational protocols for the solution	The case study adopted three protocols in addition to incentives to travel as a passenger: incentives for passengers to 'go early'; meeting places near bottlenecks for carpool formation; and methods to limit SOV travel in peak of peak. The case study route required the maximum number of people to travel as passengers from the very beginning of implementation. Other implementations might not need to achieve so much, or to achieve something different, and thus might settle on a different set of protocols. The case study assumed a level of use of prize draw entries to lower the cost of the solution. Subsequent surveying could determine the likely success of this strategy. A further optional protocol is the use of distance-based rewards, especially if dealing with consecutive bottlenecks. Other operational protocols could include provision of shuttles to the bottleneck; evening meeting-places for the return journey; charges for parking if a meeting-place parking facility is provided.
Model 20-year traffic flows based on operational assumptions	Calculate how many people will be incentivized each day to achieve the target level of traffic and forecast forward for each year. This calculation should allow for growth in demand due to population growth and economic growth. Estimate factors such as the reduction in delay compared with the current situation, and the impact on fuel use and vehicle crash rates. The case study generally used the midpoint each year as the average number to incentivize for different purposes.
Estimate 20-year costs and benefits and calculate NPV and BCR	Investigate the rates that would put benefits and costs into financial terms on a year by year basis and apply to the model. Determine the discount factor(s) to use. Carry out a sensitivity analysis around changes in parameters. For the case study, several benefit categories were not modeled such as a general economic uplift, and improvements in job satisfaction. Over time methods may become available for valuing these benefits and adding them to the assessment of congestion-clearing payments to passengers.

A SOLUTION THAT USERS WOULD DESIGN

The positive nature of passenger-payments is consistent with many of Ostrom's principles for governing the commons, as long as the users are involved in the decision-making. Because it is app-based the solution incorporates effective monitoring. Because it would be necessary to be a passenger to receive the incentives the solution does not reward people who are not part of the solution. If successful, the solution will help alleviate the tragedy of the commons usually associated with transportation systems.

A SIGNIFICANT CHANGE CHALLENGE

However, this proposal involves change on an unprecedented scale: to go from what is essentially 0% passengers to 50% passengers on the corridor, in a year, and then to maintain that level, while using incentives to spread peak demand to prevent a congestion queue at a significant bottleneck. Even though the target appears achievable based on the results of the survey, it would still be a considerable achievement. With reference to the paper by Van Vugt et al. from the Netherlands in 1982, in which a carpool lane was defeated by a combination of low usage and a challenge from those who didn't want to qualify to use it, great care should be taken to build the case, obtain positive media coverage, engage the community in a commons governance process, and establish an approach and culture that give the solution the maximum opportunity for success.

NEXT STEPS

This research from Mineta Transportation Institute began exploring the concept of passenger-payments with a positive outlook that it might make sense as a response to the peak period congestion faced every weekday by millions of U.S. workers. Following the year of research work described in this report, the concept still makes sense to the project team.

The case study corridor with its long-standing bottleneck is a single point of reference. The project team hopes to carry out research on additional corridors with different traffic conditions in order to leverage the lessons learned from this project and determine whether there are features of corridors that could be used help estimate the magnitude of, and predict the likely success of a CCPTP solution across different locations. Approaches by people in congested jurisdictions are welcomed.

Additionally, the findings of the Half Moon Bay case study justify a pilot project in that location to test the concept. The project team will pursue funding for such a pilot project in order to firm up the estimates and calibrate the findings of this study.

IMPLEMENTATION NOTES

In moving forward to a pilot project on the case study route, the project team recommends as follows to the California Department of Transport, San Mateo County, City of Half Moon Bay, and other public agencies that would be responsible for bringing it about:

1. Make commitments to fund a five-year pilot, circa $40 million present value in 2019 dollars, discounted at 3%;

2. Convene a process of Coastside community participation aligned to commons governance principles;

3. Implement detailed monitoring of the bottleneck and queues, perhaps developing or adapting some technologies to make this more effective than is currently the case;

4. Carry out counts of existing traffic for commuter:non-commuter mix and average occupancies;

5. Carry out a random sample survey of Coastside residents to validate (or adjust) the calculations contained in this report;

6. Develop options for limiting SOV travel in peak-of-peak;

7. Document a business/implementation plan that is consistent with the above;

8. Present all information to the community and seek decisions and community support for the solution;

9. With support from the community, and issues resolved, implement the plan.

The project team expects that the total 5-year cost will be below the modeled level of $40 million, because in years 3–5 a key focus will be to achieve the target level of traffic with the lowest possible cost. Gamification, prize draws, and other mechanisms including machine learning will be explored in greater detail once the commuters understand the underlying concepts of the solution.

As an end note, CCPTP is a solution that could be used for a number of years and then discontinued. The use of a 20-year timeframe for benefit and cost analysis was chosen for consistency with the usual evaluation of other alternative solutions. Especially if the cost of bottleneck location parking can be avoided, there will be minimal cost involved in shutting down the CCPTP solution if it fails to deliver the required results, or if the arrival of shared robotaxis with very low price-points renders alternative solutions unnecessary. Further, it is possible that at some point the benefit-to-cost ratio of providing incentives will fall below that of expanding the facility, at which juncture pricing will truly signal the point at which a facility should be expanded.

COVID-19

A further end note regarding COVID-19, the disease that is causing worldwide disruption to economic activity at the time the revisions to this report are being completed in April 2020. COVID-19 has removed traffic congestion to a low level that could not have been imagined. Many cities and countries are in some form of lockdown and the roads are practically empty. But this will pass.

As economies restart, the project team anticipates that there will be some permanent changes to commuting patterns as a result of two factors:

- The shift to working from home that has rapidly been achieved by middle and upper management of many organizations. This new knowledge of how to operate distributed teams will allow organizations to be leaner and more efficient and reduce demand for sustained office presence. This in turn will reduce the volume of commuter traffic.

- The mistrust by people who perceive shared transport, especially public transport, to be unsafe due to potential virus transmission. This will make it more difficult for public transport passenger counts to return to pre-virus levels, threatening the viability of transit agencies and adding to the volume of commuter traffic.

As volumes regrow, CCPTP could provide an opportunity to achieve two important things:

- Encourage commuters in a post-virus world to return to sharing by rewarding them for doing so;

- Encourage post-virus traffic to operate at a level that keeps it moving, rather than returning to the severely congested levels that the above changes might predict.

APPENDIX A: FOCUS GROUP REPORT

DESCRIPTION OF THE FOCUS GROUP METHOD

Much of what is considered standard procedure for focus group interviews may be traced to Robert Merton et al.'s classic work *The Focused Interview*.[80] The concept has been embraced wholeheartedly by market researchers, and recently has received renewed attention from academic social scientists. Richard Krueger and Mary Ann Casey define the focus group as "a special type of group in terms of purpose, size, composition, and procedures."[81,82] A focus group is typically composed of seven to ten participants who do not know each other but share common interests.

With focus groups, the researcher creates a relaxed open environment which encourages all participants to express their opinions without any mandate to reach consensus. The group discussion is repeated several times with similar types of participants to identify a broad range of perceptions.

Focus groups generally last for one to two hours. The procedure is repeated until the groups are producing relatively little that the researcher has not already heard. They are a prime example of qualitative research: Jane Farley Templeton compares and contrasts focus groups with surveys and other more quantitative research: "Focus groups do not result in numbers—or at least they should not."[83] Instead, Templeton notes the method's strength is its ability to generate working hypotheses for phenomena that can later be explored and analyzed via surveys.[84]

The method is well-suited to the exploration of topics and the generation of hypotheses. The fact that group interviews can produce useful data with relatively little direct input from the researcher, is a distinct advantage, especially in comparison to other interview techniques.[85] Focus groups can cover a broader range of topics compared to formal interviews, but they are more structured than ethnographic studies or participant observation, since they are in a controlled setting and not the world at large.

<u>Adaptation of the Focus Group Method to the Research Goals:</u> The purpose of the focus groups was to connect with and learn from the experiences of current Silicon Valley commuters. The project team wanted to provide the opportunity to discuss ideas for improving the transport system, and to introduce the concept of paying passengers as a strategy for congestion reduction as it might work for them. The participants' responses would also allow the team to generate a corpus of words, terms, and phrases related to traffic and carpooling which would inform the creation of a more detailed survey that would resonate with typical commuters' experiences, needs and issues.

Protocol Development

The protocol (see later) was formulated to include research related to how parking price and availability influences the choice to drive, to uncover information about latent demand, as well as to think about the reward curve necessary to nudge drivers to change to passengers. Questions were also included to get at psychographic segmentation: e.g., identify types of people

- who would be interested in carpooling,
- who could be convinced to give carpooling a try,
- for whom no amount of financial incentive could make carpooling appealing.

The final focus group protocol contained nine open-ended discussion questions and one written activity. Questions were structured to allow participants to talk about their experiences of commuting in congestion, to elicit suggestions for making improvements, and then to steer the conversation toward carpooling. Once the discussion of carpooling had begun, the moderator segued into evaluating pros and cons of carpooling, and eventually to asking participants to generate an incentive program for encouraging carpooling. Carpooling was not emphasized in the promotional or introductory materials, only that researchers were seeking commuters' ideas for addressed the impacts of congestion on the journey to and from work.

Participant Recruitment

Participants were recruited through a variety of means. Efforts were made to reach out to commuters who typically travel on freeways, in congestion, and alone. It was desirable to avoid recruiting people who were already involved in congestion reduction or alternative transportation. An ad was placed on Facebook targeting commuters in the area: see Figures 28-30. An incentive of $75USD in the form of a Visa gift card was offered for participants.

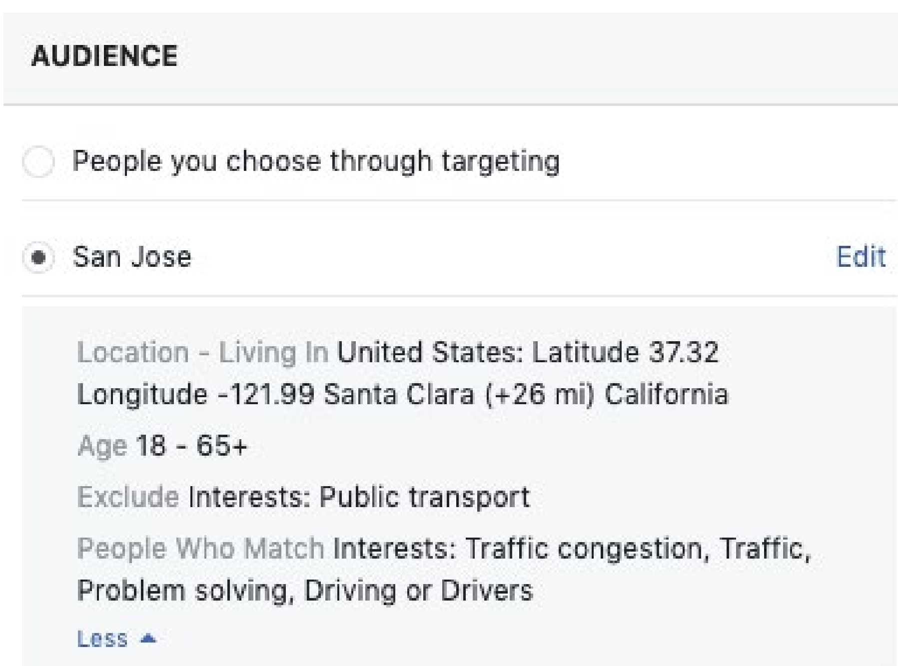


Figure 28. Audience Specification for Facebook Ad

Details

Are you a person who frequently commutes to work by car in congested traffic? We'd like your help with a focus group.

We are researchers with the Mineta Transportation Institute studying innovative and practical ways of improving commuting and reducing traffic in the Bay Area.

We hope that as a result of this research we will be able to make recommendations for new products and policies to improve commuting overall.

Participants will receive a $75 Visa Gift Card at the end of the session.

There are three sessions to choose from:
- March 14 in Central San Jose at 6:30 pm;
- March 21 in Downtown San Jose at 6:30 pm; and
- March 23 in Central San Jose at 1:30 pm.

Please register and we will provide venue details with your confirmation.

Figure 29. Details for People Who Clicked on Facebook Ad

Figure 30. Facebook Ad

San Mateo County published the survey ad from their NextDoor account, and a local traffic reporter, Gary Richardson, ran an ad for the focus groups is his weekly newspaper column “Mr. Roadshow.” The wording of the ad in the Mr. Roadshow column unfortunately included references to carpooling, but the participants recruited from his column did not appear more likely to bring up carpooling in the focus group itself. Respondents from Mr. Roadshow’s column were much more likely to be male, whereas respondents from NextDoor were more likely to be female.

Potential participants were asked to complete a Google form providing their email address, commute distance, commute duration, and preferred focus group session. When reaching out to potential participants, efforts were made to achieve a balance between male and female participants. In the end, the gender breakdown of the focus groups was as follows:

- Focus Group 1: 4 women, 4 men
- Focus Group 2: 3 women, 8 men
- Focus Group 3: 7 women, 3 men

Other demographics of the focus groups were reflective of the South Bay and Peninsula workforce: most were in their 30s and 40s with a few younger and several older participants. Latinos, Asians and Non-Hispanic Whites were well represented; one participant was African-American.

Conducting the Focus Groups

Each focus group took place in a conference room. Participants were offered beverages and refreshments. They were asked to wear name tags indicating their first names, and to complete a consent form. One of the researchers (Dr. Lee) acted as moderator, asking questions and keeping the dialogue flowing. Brittany Bogue acted as scribe and notated the responses generated by the participants. The papers from the participants were collected and the notes taken in each session were photographed to be reviewed later. Audio recordings were made of each session.

As mentioned above, the focus groups were structured to allows participants to discuss their personal experiences with commuting in traffic, then to elicit ideas for improving the transport system, and then to steer the conversation toward a discussion of carpooling. Once there, participants were asked to provide suggestions for designing a carpool incentive program. Once the group had collectively designed this program, participants were asked if such a program would influence them to begin carpooling, and if not, why not. Individually, participants were asked to write down the following:

- Their top three concerns about being a carpool driver or passenger;
- Weights for the importance of each concern by dividing 100 points among the three (e.g., if flexibility is the most important, it might receive 60 of the points, and the other 40 points would be apportioned between the other two concerns);

- The amount (incentive) they would require to travel as a carpool driver; and

- The amount they would require to travel as a carpool passenger.

Review and Analysis

After collecting the notes generated by the participants, their responses were tabulated into a spreadsheet that included the amount s/he would require to travel as a driver, as a passenger, the three most strident concerns, and the weights of each concern. Not all notes were legible, but most were. The amount required ranged from -$3 (two participants indicated they would not need to be paid if the carpool was convenient, and one even said they would pay to carpool) to $150 per day. The average amount per day was $31.24, and the median was $10. One participant suggested being paid $0.58/mile based on the government reimbursement rate. In a comment that supports the research about free parking as a driving force in the decision to drive alone, one participant indicated that free parking would be enough of an incentive to carpool. At present, this participant's destination does not offer free parking.

A frequent tirade concerned the state of enforcement of the carpool lane. In every focus group, multiple people referenced carpool cheaters who shamelessly clog up the carpool lane without having a passenger. Every group seemed to share consensus that there should be more enforcement, apart from one person who acknowledged that police presence on the road also slows down traffic. One person was particularly incensed about the carpool scofflaws and mentioned daydreams of participating in citizens' arrest and vigilante justice for wayward drivers who do not respect the sanctity of the carpool lane. Though it was a comical aside, the perception that the carpool lane is not a reliable amenity is a challenge to be overcome in efforts to reduce the number of vehicles on the road.

Survey Implications

Parking: As anticipated, very few participants pay for parking at the origin or destination of their commute. Those who pay for parking, or for whom parking is constrained tended to have a more favorable view of carpooling from the outset. These are important data for determining the price for any corridor, and questions about parking will need to be included in the survey.

Safety: Participants want to be assured that the person driving, and the person riding have been somehow vetted. This safety and comfort measure should be addressed or otherwise accounted for.

Liability: Participants were concerned about liability ramifications of carpooling.

Interpersonal Comfort: Many participants were concerned not only about the difficulty of finding a potential carpool mate, but about the suitability of that mate once identified. Segmentation should address how many of them are people who would never carpool who may place a higher premium on alone time, or the "car as inner sanctum," as one participant phrased it.

During the third focus group, in which one participant explained his experience with Scoop and implied that he was able to carpool without having to be locked into traveling with the same (potentially annoying) person(s), these concerns seemed to be assuaged. It could be that carpooling still conjures images of physical bulletin boards and rigid meeting times. While reliability is important, newer technologies make it possible to choose to carpool with potentially less advance notice and with fewer long-term social contracts.

In light of the previous bullet point, it may be beneficial to ask a question in the survey along the lines of: “How would knowing you would not need to carpool with the same people change your willingness to carpool? (less willing, no change, more willing?)”

The survey should ask about the degree of variability in the person’s commute, including variations in start and end times, and the frequency and nature of side trips on the way to and from work. It will be important to identify how necessary such deviations are in the eyes of the commuter. This assessment could help gauge how much complexity is built into respondents’ commutes, and what percentage of commuters travel to and from work without too much variability.

General Observations

Almost all the participants were currently drive-alone commuters, though most had some knowledge and experience with other modes including carpooling. Most dislike their commute, though they have adapted to it in various ways to varying degrees. Congestion, particularly severe or unexpected congestion was clearly a major if not the major factor in making their commute stressful and unpleasant. Often the trip time endured was longer than the free flow time by a factor of two or more. Most commute within or between Santa Clara and San Mateo Counties, with a few traveling to San Francisco, Santa Cruz or Alameda Counties. While some made frequent trips to the Central Valley, none resided there: several noted that they felt their own commutes were not nearly as painful as those of co-workers living in the Central Valley who endure two-hour-plus journeys to work under the best of circumstances. As expected, the afternoon commute was more congested and longer than the morning commute in almost all instances.

Driving alone in traffic is a frustrating experience in many ways. Many described their schedules as severely constrained. Typically, commuting in serious congestion means waking and leaving for work earlier than would be preferred. Some participants avoid afternoon congestion by leaving work early, but then doing some work at home in the evening. Dealing with bad and aggressive drivers was a common complaint, as were perceived roadway design deficiencies such lane drops, closely-spaced on- and off-ramps, and poorly coordinated traffic signals. Many commuters reported a notorious bottleneck; some proffered solutions, generally involving infrastructure (spot widening) or technology (better information regarding incidents, accidents, and alternative routes). Poor pavement conditions exacerbated several participants commutes, and accidents added not only travel time, but a stressful reminder that commuting can turn deadly. Several bemoaned the lack of transportation improvements, and the delays and shortcomings of those in the works. Wistful envy was expressed by some for the heyday of freeway construction in the 20th century and for “overnight” construction of major transportation infrastructure in China today.

Several women reported that their relatively short-distance commutes were lengthened temporally and complicated by the need to take children to and from school: for these commuters, enabling children to independently travel to school would facilitate carpooling. One participant noted that school holidays resulted in significant reductions in congestion, and that minor holidays (e.g. Columbus Day) that are observed by most of the public sector but not by most private firms relieve most congestion.

Takeaways for the Overall Research

Almost all the participants expressed concerns about the challenges of finding a suitable carpool companion for reasons including their location, schedule, and demeanor. Several participants were also concerned about “stranger danger” and agreed that it would be important to vet possible drivers and passengers in some manner. The number of variables concerned several participants and seemed impossible to overcome to others. To quote one participant from the second focus group, “The only way I would carpool is if the perfect person, in the perfect place could carpool with me. Money is less of a factor than location and time. Nothing would incentivize me … no amount they could pay me would make me go 5 miles out of my way.”

It’s worth noting that this comment was made during the second focus group, in which there was also a person who had attempted to use WAZE and Scoop to carpool. They had difficulty being matched with drivers or passengers. During the third focus group, a participant whose employer partners with Scoop was able to provide concrete examples of how he was able to carpool using the app with minimal inconvenience. The participant indicated that it was possible to draw a map of acceptable pick-up and drop-off locations, and to review the queue of pending riders if no one was available in the preferred zone. Having a person who could describe how one provider is able to address the perceived challenges of carpooling seemed to assuage the concerns of several of the participants in the final focus group.

Several commuters expressed tentative willingness to carpool on an occasional basis, e.g. one or two days a week. Some would like to be able to carpool one-way, e.g., ridesharing in the morning but not back in the evening. Third-party provision of carpool vehicles was proposed as an attractive strategy, as it would enable drivers as well as passengers to avoid both operating costs and liability issues. Others objected that this source of vehicles could lead to more cars on the road overall, and thus be counter-productive to energy and emissions goals and policies. Personal cars left at home might be used by other family members adding to overall vehicular travel.

During the introductions when participants were sharing details about the duration and routes of their commutes, it was clear that each driver is juggling a complex decision-making process that includes, time of day, time of year, route options, errands, and a host of other factors. Though each participant could exasperatedly rattle off the series of interchanges, departure times, durations, and bottlenecks, the descriptions of key aspects of their commute also seemed to be rote. That is to say, the number of decisions and contingency plans each driver made did not seem to carry the mental load that several perceived aspects of carpooling would require. Explicating the number of choices inherent in the decision to “just drive alone" might be instructive when communicating the mental requirements and means for shifting modes. Addressing such elements as linked trips, breakdowns, and emergency transportation is important. There is a somewhat paradoxical need to both maximize options and choices regarding carpooling, while minimizing cognitive demands and the need for complex decision-making by commuters.

FOCUS GROUP PROTOCOL

1. Recruitment

   a. Recruit on the basis of 'help improve the transport system' (not mentioning carpooling)

   b. Recruit people who make regular trips to work at the same location each day (or most days) and mostly drive alone, at peak, on a congested corridor

   c. 6–8 people for each group, meeting somewhere near their wok or their residential area

   d. A token 'thank-you' gift card worth $75

2. Introductions

   a. Inform people of their 'rights' to not answer any question, to leave at any time, to not do anything that might make them uncomfortable, to not be identified in any reports, ask them to sign the consent form, explain that we will audio-record the discussion for further analysis by team members.

   b. Ask each participant to say their name, and a description of their daily commute (type of residential area, type of work destination, amount of time it takes, and how long it would take without congestion), and how they feel about it.

   c. Quick question and answer so that everyone has a good understanding of where each other are coming from.

3. General discussion item: "What would you do to improve the transport system?"

   a. Use proper brainstorming technique where you go around the group and each person add an idea, builds on a previous idea (theirs or others'), or passes

   b. Go until all pass in a round

   c. No judgmental comments about the ideas

   d. Do a short exercise creating a classification of the ideas listed.

4. Starting to get specific:

   a. If anyone mentioned anything to do with 'encourage more carpooling' in the brainstorm, it gives us a hook into the next discussion with it being 'their' idea. Once item 3 is completed, go to that item and ask, "how would you do that?" and "what would be the issues associated with that?"

b. If the brainstorm ideas didn't include carpooling, say "you didn't say anything about encouraging more carpooling. Why not?"

c. You have to go with the flow here a bit. We can assume that they will engage in a discussion that either says "gosh, we missed that one, it should be there," or "here are several good reasons why we think it is a lousy idea," or something along those lines.

d. Either way, capture all the points they make about encouraging more carpooling on the whiteboard and probe each as far as you can [but without suggesting anything about incentives, though they might raise this].

e. Record on the board columns of 'pros' and cons' for encouraging more carpooling.

5. Getting more specific:

a. In the question 4 discussion, someone might mention 'incentivize carpooling.' If so, it gives us a hook into the next discussion with it being 'their' idea. Once item 4 is completed, go to that item and encourage a broader discussion of this idea, saying "how might you do that?" and "what would be the issues associated with that?"

b. If their ideas didn't include incentivizing carpooling, say "how about providing incentives to get more people to carpool, how would that work?"

c. Once again go with the flow. Capture points on the whiteboard about incentivizing carpooling, in columns of 'pros' and 'cons' or other categories if they seem more appropriate. Try to keep it general rather than personal.

6. And more specific:

a. Hopefully on completion of question 5 it is an easy transition to ask: "what features would an incentive program have to have, to encourage more carpooling" or "lets design the ideal incentive program for encouraging more carpooling—what does it have to have? Is there anything it should not have?" Capture the ideas on the whiteboard. [Note: this is a task even the most 'anti-carpooling' person could actively participate in].

b. Do some classifying and ranking work with what is on the whiteboard—which do they think are the most and least important features, are there some features that are really important to some people but not to others?

7. And very specific:

a. Say "if an incentive program existed on your route to work like the one you have just described on the whiteboard; would you participate in it? What do you think of as the barriers and enablers for you if you were to be a carpool driver?" [Capture all comments.]

b. Say "What do you think of as the barriers and enablers for you if you were to be a carpool passenger?" [Capture all comments.]

c. Say "How much would the incentive need to be, each day, for you to overcome those barriers and participate as a carpool driver?" [Get them all to write down their answer.]

d. Say "How much would it need to be to overcome the barriers and be a carpool passenger?" [Get them all to write down their answer.]

e. Say: "List up to three key issues that you personally considered as you answered each of those last two questions—to be a driver, and to be a passenger."

f. Say: "Please share 100 points between each of the items for being a driver, and each of the items for being a passenger (total 200 points), in proportion to how relatively important each issue was to you as you thought about it."

g. Please each share your answers to this set of questions and then we will discuss. [Record all info on the whiteboard and lead a brief discussion about interesting aspects that they talk about.]

8. Somewhat general again:

   a. Say: "The purpose of our project is to develop a method for estimating the amount of incentive needed to get enough people in a corridor to switch to being passengers so that we get rid of congestion in a transport corridor. You have helped us to better understand all the issues associated with incentivizing people to become carpoolers. Some of you have indicated that you would become a carpooler for a certain amount of incentive, while others [say this if true] have said that no amount would be sufficient. Do you think that there are different personalities of people who will carpool and people who will not? Or is it always situational? Do you have any suggestions to help us understand how personality is involved in the decision to carpool or not? What are the main factors that you think make people unwilling to carpool?"

   b. In above, pause each time to gather answers. Probe and discuss as appropriate.

9. Finally, a general question: "Our next step is (some more focus groups and) to survey a few hundred people in one corridor to find out how much these issues exist in that corridor. As we go ahead and create the survey, do you have any ideas or suggestions for us?"

Thanks for your time today. You have helped us a lot. Here is a brief summary of our project and how we are going to use the information that we have gathered today. If you have any further questions or comments, please feel free to contact Richard Lee at 123-4567 (actual contact number was provided to the participants).

APPENDIX B: SURVEY INSTRUMENT

INTRODUCTION

This appendix is made up of three components:

1. Survey summary;
2. Skip logic map for the survey; and
3. The survey itself as downloaded from SurveyMonkey.

The survey administered via SurveyMonkey had a large number of skipped pages and branches that were dependent on the earlier answers by the respondent. While the survey itself had about 105 questions, most respondents answered about 30 questions. The main driver of the skipping and branching was the mode-choice of the respondent, though there were other causes as well.

To make it easier for readers to follow the survey, it is first presented in summary form, covering the substantive content in the order that the respondents saw it, but without skips, and with wording that is similar to the survey but paraphrased for accessibility.

The two components that follow the summary could be accessed in either order, or concurrently: the questions themselves and the skip/branch logic that takes a respondent from one question to another.

SURVEY SUMMARY

1. In which community do you live?
2. On a typical Tuesday, would you usually travel on the [named] highway between 5 am and 9 am?
    a. Yes
    b. No
    c. Some Tuesdays but not every Tuesday
3. On a zero to 100-point scale, how much impact does the congestion at the bottleneck have on your decision about how and when to use the highway? (Zero = no impact, 100 = very large impact.)
4. What do you do differently because of the morning congestion at the bottleneck?
    a. I just take it as it comes
    b. I have no need to travel on the highway

c. I leave earlier to avoid the congestion at the bottleneck
d. I leave earlier to allow for the congestion at the bottleneck
e. Congestion further downstream is a bigger issue and I adjust for that
f. I leave later to avoid the congestion at the bottleneck
g. I work from or near home, I do not travel on the route because of the congestion at the bottleneck

5. What is the main purpose of your Tuesday morning trip?

6. What time do you usually leave home for your typical Tuesday morning trip?

7. Where is the destination of your typical Tuesday morning trip?

8. What mode of transport do you usually use for your typical Tuesday morning trip?

   a. Drive alone in a car, truck, or SUV
   b. Drive alone by motorcycle
   c. Drive a car, truck, SUV, van, or minibus with passengers
   d. Drive a motorcycle with passengers
   e. Travel as a passenger in a car, truck, SUV, van or minibus (but not Uber/Lyft), or on a motorcycle
   f. Travel as a sole passenger in an Uber/Lyft type of rideshare service
   g. Travel with multiple passengers in an Uber/Lyft type of rideshare service
   h. Travel as a passenger on a public transport bus

9. If in Q2 you said ‘some Tuesdays but not every Tuesday, how often do you make a Tuesday morning trip?

   a. One Tuesday a month
   b. Two Tuesdays a month
   c. Three Tuesdays a month
   d. One Tuesday every two months
   e. One Tuesday every three months
   f. One Tuesday every six months

10. If in Q8 you said e or g (travelled as a passenger) how many people, including the driver, would be in the vehicle for the Tuesday morning trip?

11. If you answered Q10, do all the people in the vehicle live in the same household, or are they from the same family?

12. If you answered Q10, is an app used to arrange these shared trips? If so, which one?

13. If in Q8 you said you travel as a driver with passengers (c or d), how many people, including the driver, would be in the vehicle for the Tuesday morning trip?

14. If you answered Q13, do all the people in the vehicle live in the same household, or are they from the same family?

15. If you answered Q13, how many of the passengers are school-age children?

16. If in Q8 you said you travel as a driver (a, b, c, or d), do you pay for parking at the destination? Is it by the hour, day, month, or year? How much is it?

17. If you answered Q16, how many seats are in your vehicle?

18. Would other days (other than Tuesday) be much different to Tuesday?

19. If you answered yes, or 'some Tuesdays' to Q2, imagine for a moment that the traffic congestion at the bottleneck has gone away. Leave aside exactly how this has happened, just imagine that it has happened. You could make trips onto the highway without any delay except the traffic lights. How would this change your use of the route on Tuesday mornings? Would you change the time you leave home? If so, what would the new time be?

20. If you answered Q19, would you change your mode of travel? If so, what would you change to?

21. If you answered Q19, if you currently travel some Tuesdays but not every Tuesday, would you change your frequency of making a Tuesday morning trip? Please select new frequency.

22. If you answered Q19, is there anything else you would change about your Tuesday morning trip-making?

23. If you answered No to Q2, imagine for a moment that the traffic congestion at the bottleneck has gone away. Leave aside exactly how this has happened, just imagine that it has happened. You could make trips onto the highway without any delay except the traffic lights. Would you start making a trip on a typical Tuesday morning?

    a. Yes
    b. No
    c. Some Tuesdays but not every Tuesday

24. If you answered Q23 with Some Tuesdays, how often would you make your new Tuesday morning trip?

25. If you answered Q23 with Yes or Some Tuesdays, what would be the main purpose

of your new Tuesday morning trip?

26. If you answered Q25, by what mode would you travel?

27. If you answered Q25, what time would you leave home?

28. If you answered Q25, what would be your destination?

29. If you answered as a driver (a to d) for Q8: As we wait and hope for a change that makes the traffic congestion disappear, are there actions that you could take in the meantime that would help make the traffic better? We are interested in what it would take for people who currently drive to travel as a passenger some of the time. This would reduce the number of cars in the backed-up traffic. This could be as a passenger on a bus, in a vanpool, in a carpool, or in a multi-passenger service such as a shuttle, UberPool, or LyftLine. Are you the sort of person who already travels as a passenger, or would travel as a passenger if it were easy to do?

    a. Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not Tuesday mornings).
    b. Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft if it were easy to do.
    c. No, I do not think I am that sort of person.

30. Some people have suggested that people who travel as passengers (in buses, vanpools, carpools, shared Uber/Lyft) should be rewarded (paid money) for doing so. Would it change your answer to the previous question if a program were in place to pay an incentive to people who travel as passengers during the times when there is traffic congestion?

    a. Yes, I am the sort of person who would travel as a passenger if it were easy to do, and if I were paid enough money each day to do so.
    b. No, I don't think I would travel as a passenger even if there was money involved.

31. You said you would not travel as a passenger even if there was money involved. Would you, instead, be prepared to give other people a ride in your vehicle?

    a. Yes, I already give other people rides some of the time (just not Tuesday mornings)
    b. Yes, I would give other people rides, if it were easy to do
    c. No, I do not think I am that sort of person

32. Would it change your answer to the previous question if passengers were being paid money for traveling as a passenger, and they were prepared to share that money with you?

a. Yes, I am the sort of person who would give people rides if it were easy to do, and if I were paid enough money each day to do so.

b. No, I don't think I would provide people with rides even if there was money involved.

33. If you are already providing rides, or if you think about providing rides, we assume it takes some effort to do so. How big is that effort? And how much money would it take to overcome that effort? On a scale of 0–100, where 0 is no effort at all and 100 is a great degree of effort, how much effort do you think it would take for you to give people a ride on your Tuesday morning trip on the [named] highway?

34. Now please imagine that a fund of money is available, say from a federal program, to pay people incentives for traveling as passengers, and the passengers are prepared to share this money with drivers. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to provide people with a ride? (Drop down box with a list of daily amounts, with an annual equivalent assuming it is done every work day.)

35. If you answered as a passenger to Q8: If you are already traveling as a passenger, or if you are thinking about traveling as a passenger, we understand that it takes some effort compared with driving alone. We'd like to know how much effort it takes for you, or how much effort you think it would take. Please answer on a scale of 0–100 where 0 is no effort at all, and 100 is a great degree of effort.

a. To travel as a passenger on a bus?

b. To travel as a passenger in a vanpool?

c. To travel as a passenger in a carpool?

36. Now please imagine that a fund of money is available, say from a federal program, to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to switch from being a driver to being a passenger in:

a. A bus (state amount)

b. A vanpool (state amount)

c. A carpool (state amount)

d. A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door? (state amount)

37. [Depending on previous answers, there are variations of the above such as how much to keep a person traveling as a passenger who said they would change to driving if the congestion had cleared.]

38. [For people who do not travel on the route but say they will start to, there are variation on the above to find out what it would take to get someone who said they would drive

to become a passenger instead.]

39. [As appropriate] You said you do not travel on the [named] highway on typical Tuesday mornings, and would still not do so if the traffic congestion went away. Would the answer be the same for other days of the working week?

40. Please could you tell us what year you were born?

41. Please tell us your gender identity.

42. What is the highest level of formal education you have completed?

    a. Less than high school graduate
    b. High school graduate
    c. Some college
    d. College graduate
    e. Postgraduate degree

43. Including yourself, how many people currently live in your household (including children)?

44. How many children in your household are age 15 or younger?

45. Number of cars usually available to people who live in your household?

46. How many people who live in your household have a driver's license?

47. Household income: what was the approximate income from employment and all other sources for all members of your household, before taxes, last year?

    a. Under $15,000
    b. Between $15,000 and $29,999
    c. Between $30,000 and $49,999
    d. Between $50,000 and $74,999
    e. Between $75,000 and $99,999
    f. Between $100,000 and $150,000
    g. Over $150,000
    h. Prefer not to say

48. Thank you for your time and effort completing this survey. If you have any comments about the survey, or about improving the traffic for [named] highway, please answer in the boxes below.

SKIP LOGIC MAP FOR THE SURVEY

Survey construction allows for skipping pages that are not relevant to some survey participants, based on their answers to earlier questions. While the survey itself has about 105 questions, most respondents answer about 30 questions. The main branches in this survey respond to mode-choice.

The following describes the skip logic that is built into the survey instrument on SurveyMonkey and relates to the survey questions that follow in the next section. P1 (immediately below) refers to the questions on Page 1 of the survey. Q1 refers to question 1. A1 refers to answer choice 1. And so on. Skip logic can be seen in each page header where relevant and following an answer-choice where a skip is present. For example:

- If the respondent chooses answer A1 to question Q1 on P1, the program will skip to the top of page 4;
- If the respondent chooses answer A2 to question Q1 on P1, the program will skip to the top of page 2;
- For P2 if there was no over-riding question-based skip, all respondents would go to the top of page 4. Because there is question-based skip logic (P2, Q2, A1, skips to top of page 4, and P2, Q2, A2, skips to the top of page 39.

The question numbers are sequential throughout the skip logic map, and link to the questions with the same number in the survey.

P1

Text

No logic

Q1

Skip logic

A1.

Yes, I agree to participate. Let's get started.

TOP OF PAGE 4

A2.

Yes, I agree to participate. But I would like to come back later.

TOP OF PAGE 2

A3.

No, I have decided that I do not want to do it.

TOP OF PAGE 3

P2

Skip logic

After the current page is completed…

Skip to

P4

Text

No logic

Q2

Skip logic

A1.

Okay, I have a bit of time, let›s get started.

TOP OF PAGE 4

A2.
No, I really have to go. I will close the link and come back later.
TOP OF PAGE 39

P3
Skip logic
After the current page is completed…
Skip to
P41

Q3
Skip logic
A1.
I didn›t mean to end up here. Please let me start the survey.
TOP OF PAGE 4
A2.
I don›t think I know enough about the issues to answer any questions.
TOP OF PAGE 41
A3.
I am just too busy right now.
TOP OF PAGE 41
A7.
Other (please tell us why)
TOP OF PAGE 41

P4
Q4
No logic

P5
Q5
Skip logic
A1.
Half Moon Bay
A2.
El Granada
A3.
Miramar
A4.
Moss Beach
A5.
Montara
A6.
Lobitos
A7.
Pescadero
A8.
San Gregorio
A9.
I do not live in this area at all
TOP OF PAGE 41
A10.
Other (please specify)

P6
Q6
Skip logic
A1.
Yes
TOP OF PAGE 7
A2.
No

TOP OF PAGE 19

A3.
Some Tuesdays but not every Tuesday

TOP OF PAGE 8

Q7
No logic

Q8
No logic

P7

Q9
No logic

Q10
No logic

Q11
No logic

Q12
No logic

Q13
No logic

Q14
Skip logic

A1.
Drive alone in a car, truck, or SUV

TOP OF PAGE 11

A2.
Drive alone by motorcycle

TOP OF PAGE 11

A3.
Drive a car, truck, SUV, van, or minibus with passengers

TOP OF PAGE 10

A4.
Drive a motorcycle with passengers

TOP OF PAGE 10

A5.
Travel as a passenger in a car, truck, SUV, van, or minibus, (but not Uber/Lyft), or on a motorcycle

TOP OF PAGE 9

A6.
Travel as a sole passenger in an Uber/Lyft type of rideshare service

TOP OF PAGE 12

A7.
Travel with multiple passengers in an Uber/Lyft type of rideshare service

TOP OF PAGE 9

A8.
Travel as a passenger on a public transport bus

TOP OF PAGE 14

A9.
Some other answer

TOP OF PAGE 11

P8

Q15
No logic

Q16
No logic

Q17
No logic

Q18

No logic
Q19
No logic
Q20
No logic
Q21
Skip logic
A1.
Drive alone in a car, truck, or SUV
TOP OF PAGE 11
A2.
Drive alone by motorcycle
TOP OF PAGE 11
A3.
Drive a car, truck, SUV, van, or minibus with passengers
TOP OF PAGE 10
A4.
Drive a motorcycle with passengers
TOP OF PAGE 10
A5.
Travel as a passenger in a car, truck, SUV, van, or minibus, (but not Uber/Lyft), or on a motorcycle
TOP OF PAGE 9
A6.
Travel as a sole passenger in an Uber/Lyft type of rideshare service
TOP OF PAGE 12
A7.
Travel with multiple passengers in an Uber/Lyft type of rideshare service
TOP OF PAGE 9
A8.
Travel as a passenger on a public transport bus
TOP OF PAGE 14
A9.
Some other answer
TOP OF PAGE 11
P9
Skip logic
After the current page is completed…
Skip to
P13
Q22
No logic
Q23
No logic
Q24
No logic
P10
Skip logic
After the current page is completed…
Skip to
P11
Q25
No logic
Q26
No logic
Q27
No logic
P11

Skip logic
After the current page is completed…
Skip to
P15

Q28
No logic
Q29
No logic
Q30
No logic

P12
Skip logic
After the current page is completed…
Skip to
P16

Q31
No logic

P13
Skip logic
After the current page is completed…
Skip to
P17

Q32
No logic

P14
Skip logic
After the current page is completed…
Skip to
P18

Q33
No logic

P15

Q34
No logic
Q35
Skip logic

A1.
No change
TOP OF PAGE 21

A2.
Drive alone in a car, truck, or SUV
TOP OF PAGE 21

A3.
Drive alone by motorcycle
TOP OF PAGE 21

A4.
Drive a car, truck, SUV, van or minibus with passengers
TOP OF PAGE 21

A5.
Drive a motorcycle with passengers
TOP OF PAGE 21

A6.
Travel as a passenger in a car, truck, SUV, van, or minibus (but not Uber/Lyft), or on a motorcycle
TOP OF PAGE 29

A7.
Travel as a sole passenger in a taxi/Uber/Lyft type of rideshare service
TOP OF PAGE 21

A8.
Travel with multiple passengers in a taxi/Uber/Lyft type of rideshare service
TOP OF PAGE 29
A9.
Travel as a passenger on a public transport bus
TOP OF PAGE 29
A10.
Other new mode
TOP OF PAGE 21

Q36
No logic

Q37
No logic

P16

Q38
No logic

Q39
Skip logic
A1.
No change
TOP OF PAGE 27
A2.
Drive alone in a car, truck, or SUV
TOP OF PAGE 27
A3.
Drive alone by motorcycle
TOP OF PAGE 27
A4.
Drive a car, truck, SUV, van or minibus with passengers
TOP OF PAGE 27
A5.
Drive a motorcycle with passengers
TOP OF PAGE 27
A6.
Travel as a passenger in a car, truck, SUV, van, or minibus (but not Uber/Lyft), or on a motorcycle
TOP OF PAGE 29
A7.
Travel as a sole passenger in a taxi/Uber/Lyft type of rideshare service
TOP OF PAGE 27
A8.
Travel with multiple passengers in a taxi/Uber/Lyft type of rideshare service
TOP OF PAGE 29
A9.
Travel as a passenger on a public transport bus
TOP OF PAGE 29
A10.
Other new mode
TOP OF PAGE 27

Q40
No logic

Q41
No logic

P17
Skip logic
After the current page is completed…
Skip to
P30

Q42

No logic

Q43

Skip logic

A1.
No change

TOP OF PAGE 29

A2.
Drive alone in a car, truck, or SUV

TOP OF PAGE 30

A3.
Drive alone by motorcycle

TOP OF PAGE 30

A4.
Drive a car, truck, SUV, van or minibus with passengers

TOP OF PAGE 30

A5.
Drive a motorcycle with passengers

TOP OF PAGE 30

A6.
Travel as a passenger in a car, truck, SUV, van, or minibus (but not Uber/Lyft), or on a motorcycle

TOP OF PAGE 29

A7.
Travel as a sole passenger in a taxi/Uber/Lyft type of rideshare service

TOP OF PAGE 30

A8.
Travel with multiple passengers in a taxi/Uber/Lyft type of rideshare service

TOP OF PAGE 29

A9.
Travel as a passenger on a public transport bus

TOP OF PAGE 29

A10.
Other new mode

TOP OF PAGE 30

Q44

No logic

Q45

No logic

P18

Q46

No logic

Q47

Skip logic

A1.
No change

TOP OF PAGE 29

A2.
Drive alone in a car, truck, or SUV

TOP OF PAGE 31

A3.
Drive alone by motorcycle

TOP OF PAGE 31

A4.
Drive a car, truck, SUV, van or minibus with passengers

TOP OF PAGE 31

A5.
Drive a motorcycle with passengers

TOP OF PAGE 31

A6.

Travel as a passenger in a car, truck, SUV, van, or minibus (but not Uber/Lyft), or on a motorcycle

TOP OF PAGE 29

A7.
Travel as a sole passenger in a taxi/Uber/Lyft type of rideshare service

TOP OF PAGE 31

A8.
Travel with multiple passengers in a taxi/Uber/Lyft type of rideshare service

TOP OF PAGE 29

A9.
Travel as a passenger on a public transport bus

TOP OF PAGE 29

A10.
Other new mode

TOP OF PAGE 31

Q48
No logic

Q49
No logic

P19

Q50
Skip logic

A1.
Yes

P20 : Q52

A2.
No

TOP OF PAGE 36

A3.
Some Tuesdays but not every Tuesday

TOP OF PAGE 20

P20

Q51
No logic

Q52
No logic

Q53
Skip logic

A1.
Drive alone in a car, truck, or SUV

TOP OF PAGE 33

A2.
Drive alone by motorcycle

TOP OF PAGE 33

A3.
Drive a car, truck, SUV, van or minibus with passengers

TOP OF PAGE 33

A4.
Drive a motorcycle with passengers

TOP OF PAGE 33

A5.
Travel as a passenger in a car, truck, SUV, van, or minibus, (but not Uber/Lyft), or on a motorcycle

TOP OF PAGE 29

A6.
Travel as a sole passenger in an Uber/Lyft type of rideshare service

TOP OF PAGE 33

A7.
Travel with multiple passengers in an Uber/Lyft type of rideshare service

TOP OF PAGE 29

A8.
Travel as a passenger on a public transport bus
TOP OF PAGE 29
A9.
Other (please specify)
TOP OF PAGE 33

Q54
No logic

Q55
No logic

Q56
No logic

P21

Q57
Skip logic
A1.
Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not Tuesday mornings).
TOP OF PAGE 26
A2.
Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft, if it were easy to do
TOP OF PAGE 26
A3.
No, I do not think I am that sort of person.
TOP OF PAGE 22

P22

Q58
Skip logic
A1.
Yes, I am the sort of person who would travel as a passenger if it were easy to do, and if I were paid enough money each day to do so.
TOP OF PAGE 26
A2.
No, I don’t think I would travel as a passenger even if there was money involved.
TOP OF PAGE 23

P23

Q59
Skip logic
A1.
Yes, I already give other people rides some of the time (just not Tuesday mornings).
TOP OF PAGE 25
A2.
Yes, I would give other people rides, if it were easy to do
TOP OF PAGE 25
A3.
No, I do not think I am that sort of person.
TOP OF PAGE 24

P24

Q60
Skip logic
A1.
Yes, I am the sort of person who would give people rides if it were easy to do, and if I were paid enough money each day to do so.
TOP OF PAGE 25
A2.
No, I don’t think I would provide people with rides even if there was money involved.

TOP OF PAGE 37

P25

Skip logic

After the current page is completed…

Skip to

P37

Q61

No logic

Q62

No logic

Q63

No logic

P26

Skip logic

After the current page is completed…

Skip to

P37

Q64

No logic

Q65

No logic

Q66

No logic

Q67

No logic

Q68

No logic

P27

Q69

Skip logic

A1.

Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not on Tuesday mornings).

TOP OF PAGE 29

A2.

Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft, if it were easy to do

TOP OF PAGE 29

A3.

No, I do not think I am that sort of person.

TOP OF PAGE 28

P28

Q70

Skip logic

A1.

Yes, I am the sort of person who would travel as a passenger in a car, van, motorcycle, bus, or multi-passenger shuttle/Uber/Lyft service if it were easy to do, and if I were paid enough money each day to do so.

TOP OF PAGE 29

A2.

No, I don't think I would travel as a passenger even if there were money involved.

TOP OF PAGE 37

P29

Skip logic

After the current page is completed…

Skip to

P37

Q71
No logic
Q72
No logic
Q73
No logic
Q74
No logic
Q75
No logic
P30
Skip logic
After the current page is completed…
Skip to
P37
Q76
No logic
Q77
No logic
Q78
No logic
Q79
No logic
P31
Q80
Skip logic
A1.
Yes, I could be convinced to continue traveling as a passenger if it were easy to do, and if I were paid enough money each day to do so.
TOP OF PAGE 32
A2.
No, I don't think I would continue traveling as a passenger even if there were money involved.
TOP OF PAGE 37
P32
Skip logic
After the current page is completed…
Skip to
P37
Q81
No logic
Q82
No logic
Q83
No logic
Q84
No logic
Q85
No logic
P33
Q86
Skip logic
A1.
Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not on Tuesday mornings).
TOP OF PAGE 35

A2.
Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft, if it were easy to do

TOP OF PAGE 35

A3.
No, I do not think I am that sort of person.

TOP OF PAGE 34

P34

Q87
Skip logic
A1.
Yes, I am the sort of person who would travel as a passenger if it were easy to do, and if I were paid enough money each day to do so.

TOP OF PAGE 35

A2.
No, I don't think I would travel as a passenger even if there were money involved.

TOP OF PAGE 37

P35

Skip logic
After the current page is completed…
Skip to
P37

Q88
No logic
Q89
No logic
Q90
No logic
Q91
No logic
Q92
No logic

P36

Q93
No logic
Q94
No logic

P37

Q95
No logic
Q96
No logic
Q97
No logic
Q98
No logic
Q99
No logic
Q100
No logic
Q101
No logic
Q102
No logic

P38
Skip logic
After the current page is completed…
Skip to
P40

Q103
No logic

P39

Q104
Skip logic
A1.
Yes
TOP OF PAGE 1
A2.
No (you will not be able to leave this page, you can only close the link).

P40
Skip logic
After the current page is completed…
Skip to
END OF SURVEY

Text
No logic

P41

Q105
Skip logic
A1.
Yes, I am happy with my answers and wish to exit the survey
END OF SURVEY
A2.
No, I would like to go back and start over
TOP OF PAGE 1
A3.
Please add a comment here if you would like to tell us your thoughts about the traffic or the survey before you exit.
END OF SURVEY

You have reached the end of the survey.

Improving Highway 92 Traffic

Introduction

Thanks for agreeing to complete this survey.

Your name was chosen at random from the Coastside voter database.

As a token of our appreciation for your time and effort, once you have completed the survey you will automatically go into a prize drawing for one of five prizes: 1 x $250, 2 x $150, and 2 x $75: Total prize pool: $700. Good luck in the prize draw, which will be drawn in August.

The purpose of this survey is to find out how (if) people use Highway 92 from Half Moon Bay towards San Mateo; how they might change how they use it if the morning congestion at the intersection with Route 1 was reduced; and what they might do in the meantime. We want to hear from people who currently travel and those who do not.

The survey takes between 7 and 13 minutes to complete. There are different pathways depending on your answers. Most people will answer around 30 questions.

Although the results of this study may be published, no information that could identify you will be included. Your responses will be kept in a password protected computer. We will separate your email and physical address data from the other fields of data so that your answers cannot be linked to you.

Your participation in this study is voluntary. If you choose to participate, you may quit the survey at any time without negative consequences.

Questions about this research may be addressed to Dr. Richard Lee by email at richard.lee@sjsu.edu or by phone at (510) 387-0996.

For questions about participants' rights or if you feel you have been harmed in any way by your participation in this study, please contact Dr. Pamela Stacks, Associate Vice President of the Office of Research, San Jose State University, at (408) 924-2479.

If you would rather complete this survey by telephone interview, please telephone Brittany Bogue at (208) 794-7504 to make arrangements.

For any question with a * before the question number, the computer will insist that you respond before moving forward.

We ask that you be as accurate as you can in your answers. There are no right or wrong answers. If you are unsure about something, please make a comment to let us know at the end of the survey, or take a screenshot and send it to richard.lee@sjsu.edu.

AGREEMENT TO PARTICIPATE
Please select from the choices below. If you click agree, it is implied that you have read the information above about the research, your rights as a participant, and give your voluntary consent. Please print out a copy of this page and keep it for your records

Kind regards,

Dr. Richard Lee
San Jose State University
richard.lee@sjsu.edu
(510) 387-0996

* 1. Do you agree to participate in the survey?

- ◯ Yes, I agree to participate. Let's get started.
- ◯ Yes, I agree to participate. But I would like to come back later.
- ◯ No, I have decided that I do not want to do it.

Improving Highway 92 Traffic

Come Back Later

If you do not have time to do the whole survey right now, you could get started and then come back later to finish it off.

As long as you do not click 'done', and use the same computer, it will remember how far you got, and the answers you gave so far.

If you do not have time right now, please use the same link to come back later. We would really like to hear your opinions.

* 2. Would you like to get started now and see how far you get?

- ◯ Okay, I have a bit of time, let's get started.
- ◯ No, I really have to go. I will close the link and come back later.

Improving Highway 92 Traffic

Reasons for not completing the survey

* 3. You have decided not to do the survey.

No worries. We would have liked to hear your opinions, but we respect that you do not want to tell us.

Would you take a moment to tell us why not?

- ◯ I didn't mean to end up here. Please let me start the survey.
- ◯ I don't think I know enough about the issues to answer any questions.
- ◯ I am just too busy right now.
- ◯ Other (please tell us why)

Improving Highway 92 Traffic

What should we call you?

* 4. What would you like us to call you while you complete the survey? Please write your preferred name or nickname in the box.

Improving Highway 92 Traffic

In which suburb do you live?

* 5. Thanks [Q4]. We want to hear from people who live in the vicinity of Half Moon Bay, California. In which community do you live?

- Half Moon Bay
- El Granada
- Miramar
- Moss Beach
- Montara
- Lobitos
- Pescadero
- San Gregorio
- I do not live in this area at all
- Other (please specify)

Improving Highway 92 Traffic

Typical Tuesday Morning Trips

* 6. Thanks [Q4] from [Q5]. This survey is about how people use Highway 92 from Half Moon Bay to San Mateo.

We know that there is a lot of traffic congestion in the morning around the intersection with Route 1.

In order to focus our work, we are asking people about the trips they make on typical Tuesday mornings throughout the year.

[Q4], on a typical Tuesday, would you usually travel on Highway 92 from Half Moon Bay towards San Mateo between the hours of 5 am and 9 am?

- ◯ Yes
- ◯ No
- ◯ Some Tuesdays but not every Tuesday

7. Does the morning traffic congestion have an impact on your decision about if, how, and when to travel on this route?

Please tell us on a 100 point scale, from zero, where it has no impact, to 100, where it has a very large impact.

The morning traffic congestion has no impact on my decision about how and when to travel this route.	The morning traffic congestion has a very large impact on my decision about how and when to travel this route.

8. Please briefly explain your answer to the previous question. What do you do differently because of the morning traffic congestion on the route? Please select one answer that BEST reflects your meaning, or describe more fully in the comments box.

- ◯ I don't do anything differently because of the traffic congestion, I just take it as it comes.
- ◯ I have no need to travel on Highway 92.
- ◯ I leave earlier in the morning to avoid the congestion at Route 1/Highway 92.
- ◯ I leave earlier in the morning so that I have enough time for the congestion at Route 1/Highway 92.
- ◯ The congestion after the SR 280 is more of an issue than the Route 1/Highway 92 congestion and I adjust for that.
- ◯ I leave later in the morning to avoid the congestion at Route 1/Highway 92.
- ◯ I work from or near home; I do not travel on Highway 92 because of the congestion.

Other or additional explanation:

Improving Highway 92 Traffic

Trip purpose, details, and mode

9. [Q4], what is the main purpose of your Tuesday morning trip? Please choose one answer from the list below, or write another purpose in the box.

- ◯ Work
- ◯ Education (for self)
- ◯ Education for passenger(s) under 16 years
- ◯ Education for passenger(s) over 16 years
- ◯ Social or Recreational
- ◯ Shopping
- ◯ Health related (doctor's appointments, for example)
- ◯ Some other purpose? Or if it is difficult to say what is the main purpose for a mixed-purpose trip? Please record these purposes here:

* 10. What time do you usually leave from home for your typical Tuesday morning trip? Please choose the time from the drop-down box that is closest to when you leave, or if you prefer, put the exact time in the box.

* 11. Where is the destination of your typical Tuesday morning trip? Please choose from the alphabetical drop-down list, or, if your destination is not listed, please write it in the box below.

12. How many miles is your trip? (one way)?

13. How long (in minutes) does it take you to get there on a typical Tuesday morning? Please choose from the drop-down list, or if you prefer, write a more precise time in the box below.

A more precise time? Please record it here.

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* 14. [Q4], what mode of transport do you usually use for your Tuesday morning trip?

Please select the most accurate response from the list below, or if what you do is not listed, please tell us in the 'other' box.

- ◯ Drive alone in a car, truck, or SUV
- ◯ Drive alone by motorcycle
- ◯ Drive a car, truck, SUV, van, or minibus with passengers
- ◯ Drive a motorcycle with passengers
- ◯ Travel as a passenger in a car, truck, SUV, van, or minibus, (but not Uber/Lyft), or on a motorcycle
- ◯ Travel as a sole passenger in an Uber/Lyft type of rideshare service
- ◯ Travel with multiple passengers in an Uber/Lyft type of rideshare service
- ◯ Travel as a passenger on a public transport bus
- ◯ Some other answer

Improving Highway 92 Traffic

Trip purpose, details, and mode

* 15. When you said 'some Tuesdays but not every Tuesday', how often do you make a Tuesday morning trip? Please select your frequency from the list below.

16. [Q4], what is the main purpose of your occasional Tuesday morning trip? Please choose one answer from the list below, or write another purpose in the box.

- ◯ Work
- ◯ Education (for self)
- ◯ Education for passenger(s) under 16 years
- ◯ Education for passenger(s) over 16 years
- ◯ Social or Recreational
- ◯ Shopping
- ◯ Health related (doctor's appointments, for example)
- ◯ Some other purpose? Or if it is difficult to say what is the main purpose for a mixed-purpose trip? Please record these purposes here:

* 17. What time do you usually leave from home for your occasional Tuesday morning trip? Please choose the time from the drop-down box that is closest to when you leave, or if you prefer, put the exact time in the box.

* 18. Where is the destination of your occasional Tuesday morning trips? Please choose from the alphabetical drop-down list, or, if your destination is not listed, please write it in the box below.

19. How many miles is your trip? (one way)?

20. How long (in minutes) does it take you to get there on a typical Tuesday morning? Please choose from the drop-down list, or if you prefer, write a more precise time in the box below.

A more precise time? Please record it here.

* 21. [Q4], what mode of transport do you usually use for your Tuesday morning trip?

Please select the most accurate response from the list below, or if what you do is not listed, please tell us in the 'other' box.

- Drive alone in a car, truck, or SUV
- Drive alone by motorcycle
- Drive a car, truck, SUV, van, or minibus with passengers
- Drive a motorcycle with passengers
- Travel as a passenger in a car, truck, SUV, van, or minibus, (but not Uber/Lyft), or on a motorcycle
- Travel as a sole passenger in an Uber/Lyft type of rideshare service
- Travel with multiple passengers in an Uber/Lyft type of rideshare service
- Travel as a passenger on a public transport bus
- Some other answer

Improving Highway 92 Traffic

Traveling as a passenger, details

22. You said you travel as a passenger in a car, truck, SUV, van, minibus or motorcycle, or in a multi-passenger Uber/Lyft. Please indicate how many people (in total including the driver and passenger(s)) would be in the vehicle for the Tuesday morning trip.

Some other answer? Please put it here.

23. And in the case of these trips with passengers, do all the people in the vehicle live in the same household, or are they all from the same family? Please choose the answer that fits best with your situation.

- Yes, all in the same household or from the same family
- No, none are in the same household or from the same family
- Some do and some don't/some are and some aren't (please explain)

24. Is an app used to arrange these shared trips? If so, which app(s).

Improving Highway 92 Traffic

Driving with passengers, details

25. You said you travel as a driver with passenger(s). Please indicate how many people (in total including the driver and passenger(s)) would be in the vehicle for the Tuesday morning trip.

Some other answer? Please put it here.

26. And in the case of these trips with passengers, do all the people in the vehicle live in the same household, or are they all from the same family? Please choose the answer that fits best with your situation.

- Yes, all in the same household or from the same family
- No, none are in the same household or from the same family
- Some do and some don't/some are and some aren't (please explain)

27. How many of the passengers are school-age children?

Improving Highway 92 Traffic

Parking Costs

28. Do you pay for parking at the destination? If so, is it by the hour, day, week, month, or year? And how much is it? Please choose from the drop-down lists, and if your amount is not in the list please write it in the box below.

	Pay for Parking?	Time paid for	Amount paid
I pay the following for parking			

Other Amount

29. How many seats are there in your vehicle?

30. Thanks [Q4] for all that information. We picked Tuesday to focus on because Tuesday's traffic is usually the worst of the week. If we had asked about a different day of the work-week, would your answer be any different? If so, please explain briefly what you do differently on other days of the work-week.

- ◯ My answer would be the same for any day of the work-week
- ◯ Other days are different as follows:

Improving Highway 92 Traffic

Is Tuesday typical?

31. Thanks [Q4] for all that information. We picked Tuesday to focus on because Tuesday's traffic is usually the worst of the week. If we had asked about a different day of the work-week, would your answer be any different? If so, please explain briefly what you do differently on other days of the work-week.

- ◯ My answer would be the same for any day of the work-week
- ◯ Other days are different as follows:

Improving Highway 92 Traffic

Is Tuesday typical?

32. Thanks [Q4] for all that information. We picked Tuesday to focus on because Tuesday's traffic is usually the worst of the week. If we had asked about a different day of the work-week, would your answer be any different? If so, please explain briefly what you do differently on other days of the work-week.

- ◯ My answer would be the same for any day of the work-week
- ◯ Other days are different as follows:

Improving Highway 92 Traffic

Is Tuesday typical?

33. Thanks [Q4] for all that information. We picked Tuesday to focus on because Tuesday's traffic is usually the worst of the week. If we had asked about a different day of the work-week, would your answer be any different? If so, please explain briefly what you do differently on other days of the work-week.

- ○ My answer would be the same for any day of the work-week
- ○ Other days are different as follows:

Improving Highway 92 Traffic

What would you do if the traffic congestion went away?

Please imagine for a moment that the morning traffic congestion around the Route 1/Highway 92 intersection has gone away. Leave aside exactly how this has happened, just imagine that it has happened.

You could reliably make trips onto Highway 92 without any delay except the traffic lights.

How would this change your use of the route on Tuesday mornings? If you leave early at the moment, would you leave later? If you leave later at the moment, would you leave earlier? Would you change your mode of travel? If you travel occasional Tuesdays at the moment, would you increase your frequency of Tuesday travel?

* 34. If the congestion was gone, [Q4], would you change the time you leave home? If so, what time would you leave home?

* 35. If the congestion was gone, [Q4], would you change your mode of travel? If so, what would you change to?

36. If you currently travel 'some Tuesdays but not every Tuesday', would you change your frequency of making a Tuesday morning trip? If so, please select your new frequency from the list below.

37. Is there anything else that you would change about your Tuesday morning trip-making?

Improving Highway 92 Traffic

What would you do if the traffic congestion went away?

Please imagine for a moment that the morning traffic congestion around the Route 1/Highway 92 intersection has gone away. Leave aside exactly how this has happened, just imagine that it has happened.

You could reliably make trips onto Highway 92 without any delay except the traffic lights.

How would this change your use of the route on a typical Tuesday morning? If you leave early at the moment, would you leave later? If you leave later at the moment, would you leave earlier? Would you change your mode of travel? If you travel occasional Tuesdays at the moment, would you increase your frequency of Tuesday travel?

* 38. If the congestion was gone, [Q4], would you change the time you leave home? If so, what time would you leave home?

* 39. If the congestion was gone, [Q4], would you change your mode of travel? If so, what would you change to?

40. If you currently travel 'some Tuesdays but not every Tuesday', would you change your frequency of making a Tuesday morning trip? If so, please select your new frequency from the list below.

41. Is there anything else that you would change about your Tuesday morning trip-making?

Improving Highway 92 Traffic

What would you do if the traffic congestion went away?

Please imagine for a moment that the morning traffic congestion around the Route 1/Highway 92 intersection has gone away. Leave aside exactly how this has happened, just imagine that it has happened.

You could reliably make trips onto Highway 92 without any delay except the traffic lights.

How would this change your use of the route on a typical Tuesday morning? If you leave early at the moment, would you leave later? If you leave later at the moment, would you leave earlier? Would you change your mode of travel? If you travel occasional Tuesdays at the moment, would you increase your frequency of Tuesday travel?

* 42. If the congestion was gone, [Q4], would you change the time you leave home? If so, what time would you leave home?

* 43. If the congestion was gone, [Q4], would you change your mode of travel? If so, what would you change to?

44. If you currently travel 'some Tuesdays but not every Tuesday', would you change your frequency of making a Tuesday morning trip? If so, please select your new frequency from the list below.

45. Is there anything else that you would change about your Tuesday morning trip-making?

Improving Highway 92 Traffic

What would you do if the traffic congestion went away?

Please imagine for a moment that the morning traffic congestion around the Route 1/Highway 92 intersection has gone away. Leave aside exactly how this has happened, just imagine that it has happened.

You could reliably make trips onto Highway 92 without any delay except the traffic lights.

How would this change your use of the route on a typical Tuesday morning? If you leave early at the moment, would you leave later? If you leave later at the moment, would you leave earlier? Would you change your mode of travel? If you travel occasional Tuesdays at the moment, would you increase your frequency of Tuesday travel?

* 46. If the congestion was gone, [Q4], would you change the time you leave home? If so, what time would you leave home?

* 47. If the congestion was gone, [Q4], would you change your mode of travel? If so, what would you change to?

48. If you currently travel 'some Tuesdays but not every Tuesday', would you change your frequency of making a Tuesday morning trip? If so, please select your new frequency from the list below.

49. Is there anything else that you would change about your Tuesday morning trip-making?

Improving Highway 92 Traffic

What would you do if the traffic congestion went away?

Please imagine for a moment that the morning traffic congestion around the Route 1/Highway 92 intersection has gone away. Leave aside exactly how this has happened, just imagine that it has happened.

You could reliably make trips onto Highway 92 without any delay except the traffic lights.

Would you start making a trip on a typical Tuesday morning? If so, what would it look like?

* 50. If the congestion was gone, [Q4], would you start making a trip on a typical Tuesday morning?

- Yes
- No
- Some Tuesdays but not every Tuesday

Improving Highway 92 Traffic

New Tuesday Traveler trip details

* 51. When you said 'some Tuesdays but not every Tuesday', how often would you make your new Tuesday morning trip? Please select your frequency from the list below.

52. And what would be the main purpose of your new Tuesday morning trip?

- Work
- Education (for self)
- Education for passenger(s) under 16 years
- Education for passenger(s) over 16 years
- Social or Recreational
- Shopping
- Health related (doctor's appointments, for example)
- Some other purpose? Or if it is difficult to say what is the main purpose for a mixed-purpose trip? Please record these purposes here:

* 53. By what mode would you travel?

- Drive alone in a car, truck, or SUV
- Drive alone by motorcycle
- Drive a car, truck, SUV, van or minibus with passengers
- Drive a motorcycle with passengers
- Travel as a passenger in a car, truck, SUV, van, or minibus, (but not Uber/Lyft), or on a motorcycle
- Travel as a sole passenger in an Uber/Lyft type of rideshare service
- Travel with multiple passengers in an Uber/Lyft type of rideshare service
- Travel as a passenger on a public transport bus
- Other (please specify)

* 54. What time in the morning would you leave home?

* 55. What would be your destination for your new Tuesday morning trip? Please choose from the alphabetical drop-down list, or, if your destination is not listed, please write it in the box below.

56. How far is it, in miles, one way?

Improving Highway 92 Traffic

What will you do in the meantime?

As we wait and hope for a change that makes the traffic congestion disappear, are there actions that you could take in the meantime that would help make the traffic better?

We are interested in what it would take to get people who currently drive to travel as a passenger some of the time. This would reduce the number of cars in the backed up traffic. This could be travel as a passenger on a bus, in a vanpool, or in a carpool, or a multi-passenger service such as a shuttle, UberPool, or LyftLine.

* 57. [Q4], are you the sort of person who already travels as a passenger, or would travel as a passenger if it was easy to do?

- Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not Tuesday mornings).
- Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft, if it were easy to do
- No, I do not think I am that sort of person.

Would you like to explain your answer in any way?

Improving Highway 92 Traffic

Would you do it for money?

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* 58. Some people have suggested that people who travel as passengers (in buses, vanpools, carpools, shared Uber/Lyft) should be rewarded (paid money) for doing so. Would it change your answer to the previous question if a program were in place to pay an incentive to people who travel as passengers during the times when there is traffic congestion?

- ◯ Yes, I am the sort of person who would travel as a passenger if it were easy to do, and if I were paid enough money each day to do so.
- ◯ No, I don't think I would travel as a passenger even if there was money involved.

Add a comment if you would like to.

Improving Highway 92 Traffic

Will you provide rides for other people?

* 59. [Q4], you said you would not travel as a passenger, even if there was money involved. Would you, instead, be prepared to give other people a ride in your vehicle?

- ◯ Yes, I already give other people rides some of the time (just not Tuesday mornings).
- ◯ Yes, I would give other people rides, if it were easy to do
- ◯ No, I do not think I am that sort of person.

Would you like to explain your answer in any way?

Improving Highway 92 Traffic

How much money?

* 60. Would it change your answer to the previous question if passengers were being paid money for traveling as a passenger, and they were prepared to share that money with you?

- ◯ Yes, I am the sort of person who would give people rides if it were easy to do, and if I were paid enough money each day to do so.
- ◯ No, I don't think I would provide people with rides even if there was money involved.

Add a comment if you would like to.

Improving Highway 92 Traffic

How much effort to provide rides, how much money?

If you are already providing rides, or if you think about providing rides, we assume it takes some effort to do so. How big is that effort? And how much money would it take to overcome that effort?

61. How much effort do you think it would take for you to give people a ride on your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	GIVE PEOPLE A RIDE	A great amount of effort

62. [Q4], now please imagine that a fund of money is available, say from a federal program, to pay people incentives for traveling as passengers, and the passengers are prepared to share this money with drivers. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to provide people with a ride?

	Daily amounts
Your price for providing a ride	

If you would like to specify an amount that is different to what is offered above, please do so here.

63. You have told us the amount you would want to be paid to give someone a ride for your [Q12][Q19][56] mile trip. Other people will tell us different amounts for different distances. To make it easier for us to compare, please think about if your trip were from Half Moon Bay to downtown San Mateo, which is 13 miles, how much would you need to be paid to give someone a ride for that trip (please skip if your trip is from Half Moon Bay to San Mateo):

	Daily amounts
Your price for providing a standard distance ride	

If you would like to specify a different amount please do so here:

Improving Highway 92 Traffic

Effort to travel as a passenger

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If you are already traveling as a passenger, or if you are thinking about traveling as a passenger, we understand that it takes some effort compared with driving alone. We'd like to know how much effort it takes for you, or how much effort you think it would take.

64. How much effort do you think it would take for you to travel as a passenger on a BUS for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	BUS	A great amount of effort	

65. How much effort do you think it would take for you to travel as a passenger in a VANPOOL for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	VANPOOL	A great amount of effort	

66. How much effort do you think it would take for you to travel as a passenger in a CARPOOL for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	CARPOOL	A great amount of effort	

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67. [Q4], now please imagine that a fund of money is available, say from a federal program, to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to switch from being a driver, to being a passenger in:

	Daily amount you would need to be paid
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify an amount that is different to what is offered above, please do so here. Please write 'bus amount', 'vanpool amount', etc.

68. You have told us the amount of incentive you would need to travel as a passenger for your [Q12][Q19][Q56] mile trip. Other people will tell us different amounts for different distances. To make it easier for us to compare, please think about if your trip were from Half Moon Bay to downtown San Mateo, which is 13 miles, how much would you need to be paid to travel that trip as a passenger in: (please skip if your trip is from Half Moon Bay to San Mateo):

	Daily amount you would need to be paid for standard distance trip
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify a different amount please do so here:

Improving Highway 92 Traffic

What will you do in the meantime?

As we wait and hope for a change that makes the traffic congestion disappear, are there actions

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that you could take in the meantime that would help make the traffic better?

We are interested in what it would take to get people who currently drive, or travel as solo passengers in taxi/Uber/Lyft services, to travel as a passenger in car, van, bus, motorcycle, or multi-passenger shuttle/Uber/Lyft services some of the time.

* 69. [Q4], are you the sort of person who already travels as a passenger, or would travel as a passenger if it was easy to do?

- ◯ Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not on Tuesday mornings).
- ◯ Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft, if it were easy to do
- ◯ No, I do not think I am that sort of person.

Would you like to explain your answer in any way?

Improving Highway 92 Traffic

Would you do it for money?

* 70. Some people have suggested that people who travel as passengers (in buses, vanpools, carpools, shared Uber/Lyft) should be rewarded (paid money) for doing so. Would it change your answer to the previous question if a program were in place to pay an incentive to people who travel as passengers during the times when there is traffic congestion?

- ◯ Yes, I am the sort of person who would travel as a passenger in a car, van, motorcycle, bus, or multi-passenger shuttle/Uber/Lyft service if it were easy to do, and if I were paid enough money each day to do so.
- ◯ No, I don’t think I would travel as a passenger even if there were money involved.

Add a comment if you would like to.

Improving Highway 92 Traffic

Effort to travel as a passenger

If you are already traveling as a passenger, or if you are thinking about traveling as a passenger, we understand that it takes some effort compared with driving alone. We'd like to know how much effort it takes for you, or how much effort you think it would take.

71. How much effort is or would be involved for you to travel as a passenger on a BUS for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	BUS	A great amount of effort

72. How much effort is or would be involved for you to travel as a passenger in a VANPOOL for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	VANPOOL	A great amount of effort

73. How much effort is or would be involved for you to travel as a passenger in a CARPOOL for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	CARPOOL	A great amount of effort

74. [Q4], now please imagine that a fund of money is available, say from a federal program, to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to switch to, or continue being a passenger in:

	Daily amount you would need to be paid
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify an amount that is different to what is offered above, please do so here. Please write 'bus amount', 'vanpool amount', etc.

22

75. You have told us the amount of incentive you would need to travel as a passenger for your [Q12] [Q19] mile trip. Other people will tell us different amounts for different distances. To make it easier for us to compare, please think about if your trip were from Half Moon Bay to downtown San Mateo, which is 13 miles, how much would you need to be paid to travel that trip as a passenger in: (please skip if your trip is from Half Moon Bay to San Mateo):

	Daily amount you would need to be paid for standard distance trip
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify a different amount please do so here:

Improving Highway 92 Traffic

What will you do in the meantime?

As we wait and hope for a change that makes the traffic congestion disappear, are there actions that you could take in the meantime that would help make the traffic better?

You said you currently travel as a passenger, but if the traffic congestion disappeared, you would switch to traveling as a driver or solo taxi/Uber/Lyft rider. We are interested in what it would take to keep you traveling as a passenger on a bus, in a vanpool, or in a carpool, or a multi-passenger service such as a shuttle, UberPool, or LyftLine.

76. How much effort do you think it would take for you to travel as a passenger on a BUS for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all | BUS | A great amount of effort

77. How much effort do you think it would take for you to continue your travel as a passenger in a car, van, motorcycle, or multi-passenger shuttle/Uber/Lyft service for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	EXISTING PASSENGER TRAVEL	A great amount of effort

78. [Q4], now please imagine that a fund of money is available, say from a federal program, to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to NOT switch to being a driver, but switching or continuing to be a passenger in:

	Daily amount you would need to be paid
A bus?	
A car, van, motorcycle?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify an amount that is different to what is offered above, please do so here. Please write 'bus amount', 'car amount', etc.

79. You have told us the amount of incentive you would need to continue traveling as a passenger for your [Q12][Q19][Q56] mile trip. Other people will tell us different amounts for different distances. To make it easier for us to compare, please think about if your trip were from Half Moon Bay to downtown San Mateo, which is 13 miles, how much would you need to be paid to NOT switch to driving but travel that trip as a passenger in: (please skip if your trip is from Half Moon Bay to San Mateo):

	Daily amount you would need to be paid for standard distance trip
A bus?	
A car, van, or motorcycle?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify a different amount please do so here:

Improving Highway 92 Traffic

What will you do in the meantime?

As we wait and hope for a change that makes the traffic congestion disappear, are there actions that you could take in the meantime that would help make the traffic better?

You currently travel by bus, but you have said you would switch to being a driver if the traffic congestion disappeared. We are interested in what it would take to get you to continue traveling as a passenger some of the time. This could be continuing to travel as a passenger on a bus, or in a van, a car, or a multi-passenger service such as a shuttle, UberPool, or LyftLine.

* 80. Some people have suggested that people who travel as passengers (in buses, vanpools, carpools, shared Uber/Lyft) should be rewarded (paid money) for doing so. Would it convince you to not start driving if a program were in place to pay an incentive to people who travel as passengers during the times when there is traffic congestion?

- ◯ Yes, I could be convinced to continue traveling as a passenger if it were easy to do, and if I were paid enough money each day to do so.
- ◯ No, I don’t think I would continue traveling as a passenger even if there were money involved.

Add a comment if you would like to.

Improving Highway 92 Traffic

Effort for bus passengers to change

If you are already traveling as a bus passenger, or if you are thinking about traveling as a bus passenger, we understand that it takes some effort compared with driving. We'd like to know how much effort it takes for you, or how much effort you think it would take.

81. How much effort is involved, or would be involved, in traveling as a passenger on a BUS for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all | BUS | A great amount of effort

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82. How much effort do you think it would take for you to travel as a passenger in a VANPOOL for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	VANPOOL	A great amount of effort	

83. How much effort do you think it would take for you to travel as a passenger in a CARPOOL for your Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	CARPOOL	A great amount of effort	

84. [Q4], now please imagine that a fund of money is available, say from a federal program, to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so, (perhaps it saves time) how much would you need to be paid, on Tuesdays, to not switch to being a driver, but continuing to be, or becoming a passenger in:

	Daily amount you would need to be paid
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify an amount that is different to what is offered above, please do so here. Please write 'bus amount', 'vanpool amount', etc.

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85. You have told us the amount of incentive you would need to continue traveling as a passenger for your [Q12][Q19][Q56] mile trip. Other people will tell us different amounts for different distances. To make it easier for us to compare, please think about if your trip were from Half Moon Bay to downtown San Mateo, which is 13 miles, how much would you need to be paid to travel that trip as a passenger in: (please skip if your trip is from Half Moon Bay to San Mateo):

	Daily amount you would need to be paid for standard distance trip
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify a different amount please do so here:

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What will you do in the meantime?

As we wait and hope for a change that makes the traffic congestion disappear, are there actions that you could take in the meantime that would help make the traffic better?

You have indicated that you do not currently travel on Highway 92 on Tuesday mornings but that you would begin to do so as a driver or solo taxi/Uber/Lyft rider if the traffic congestion disappeared. We are interested in what it would take to get you to travel as a passenger instead. This could be travel as a passenger on a bus, in a vanpool, or in a carpool, or a multi-passenger service such as a shuttle, UberPool, or LyftLine.

* 86. [Q4], are you the sort of person who already travels as a passenger, or would travel as a passenger if it was easy to do?

- ◯ Yes, I already travel as a passenger (excluding sole occupant of taxi/Uber/Lyft) some of the time (just not on Tuesday mornings).
- ◯ Yes, I am the sort of person who would travel as a passenger, including a multi-passenger taxi/Uber/Lyft, if it were easy to do
- ◯ No, I do not think I am that sort of person.

Would you like to explain your answer in any way?

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Would you do it for money?

* 87. Some people have suggested that people who travel as passengers (in buses, vanpools, carpools, shared Uber/Lyft) should be rewarded (paid money) for doing so. Would it change your answer to the previous question if a program were in place to pay an incentive to people who travel as passengers during the times when there is traffic congestion?

- ◯ Yes, I am the sort of person who would travel as a passenger if it were easy to do, and if I were paid enough money each day to do so.
- ◯ No, I don’t think I would travel as a passenger even if there were money involved.

Add a comment if you would like to.

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Effort involved in starting as a new passenger

If you are thinking about traveling as a passenger, we understand that it takes some effort compared with driving alone. We'd like to know how much effort you think it would take.

88. How much effort do you think it would take for you to travel as a passenger on a BUS for your new Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all — BUS — A great amount of effort

89. How much effort do you think it would take for you to travel as a passenger in a VANPOOL for your new Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all — VANPOOL — A great amount of effort

90. How much effort do you think it would take for you to travel as a passenger in a CARPOOL for your new Tuesday morning trip on Highway 92? Please answer on a scale of 0 – 100, where 0 is no effort at all, and 100 is a great degree of effort.

No effort at all	CARPOOL	A great amount of effort	

91. [Q4], now please imagine that a fund of money is available, say from a federal program, to pay people an incentive for traveling as a passenger. Assuming it does not add any time to your journey to do so, (perhaps it saves time), how much would you need to be paid, on Tuesdays, to make your new trip as a passenger (instead of as a driver) in:

	Daily amount you would need to be paid
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify an amount that is different to what is offered above, please do so here. Please write 'bus amount', 'vanpool amount', etc.

92. You have told us the amount of incentive you would need to travel as a passenger for your new [Q12][Q19][Q56] mile trip. Other people will tell us different amounts for different distances. To make it easier for us to compare, please think about if your new trip were from Half Moon Bay to downtown San Mateo, which is 13 miles, how much would you need to be paid to travel that trip as a passenger in: (please skip if your trip new trip would be from Half Moon Bay to San Mateo):

	Daily amount you would need to be paid for standard distance trip
A bus?	
A vanpool?	
A carpool?	
A shuttle or Uber-Pool or Lyft-Line type of multi-passenger shared ride service that picks you up at your door?	

If you would like to specify a different amount please do so here:

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Are Tuesdays Typical?

93. [Q4], you have said that you do not travel on Highway 92 on typical Tuesday mornings, and would still not travel on Highway 92 on typical Tuesday mornings if the traffic congestion went away. Would the answer be the same for the other days of the working week?

- Yes
- No

If no, please could you tell us what happens on other days, in this answer box:

94. Our sample was generated at random, and we wanted to hear from people who use the Highway and people who do not. You are an important part of the total population, for helping us get a complete picture. We appreciate that you have taken the time to tell us. Except for a few demographic questions that come next, we have no further questions for you.
However, if you have any comments for us about the congestion on Highway 92, and any ways it impacts on you, please tell us in the box.

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Demographic Details

We have almost finished. To end the survey we ask that you answer the following questions so that we can make sure our sample is representative of the general population.

95. Please tell us in what year you were born? Please select the year from the drop down box.

96. [Q4], please tell us your gender identity?

- Male
- Female
- Other

97. What is the highest level of formal education you have completed?

- Less than high school graduate
- High school graduate
- Some college
- College graduate
- Postgraduate degree

98. Including yourself, how many people currently live in your household (including children)? (Please answer in number format).

99. How many children in your household are age 15 or younger?

100. Number of cars usually available to people who live in your household?

101. How many people who live in your household have a driver's licence?

102. Household Income: What was the approximate annual income from employment and all other sources for all members of your household, before taxes, last year?

- Under $15,000
- Between $15,000 and $29,999
- Between $30,000 and $49,999
- Between $50,000 and $74,999
- Between $75,000 and $99,999
- Between $100,000 and $150,000
- Over $150,000
- Prefer not to say

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Thanks for your time

103. Thank you so much, [Q4] from [Q5], for your time and effort completing this survey.

If you have any comments about the survey, or about improving the traffic for Highway 92, please answer in the boxes below.

Comments about this survey: what you liked or didn't like, or suggestions.

Comments about improving the traffic on Highway 92 that we might not have covered.

If you would like us to respond to these comments, please say so here.

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Close the link and come back later

You chose to come back later. Please just close the link. Use the same computer and use the same link, and you will be returned to this page.

104. Would you like to go to the beginning of the survey?

- Yes
- No (you will not be able to leave this page, you can only close the link).

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End of Survey

That is the end of the survey. When you click 'Next' the survey will close. Thank you for contributing your ideas, experiences, opinions, and time. As promised, completing the survey qualifies you to go into our prize drawing for one of five prizes. Thanks again, and good luck in the draw.

Improving Highway 92 Traffic

Rejection Page

If you have arrived at this page, you have been rejected from completing the survey due to an answer that you have given. If you didn't intend to give that answer, please say so below and you will be returned to the beginning of the survey. If you did intend to give that answer, please click 'Done' and you will exit the survey. Thank you for your time and interest.

105. [Q4], did you intend to give the answer that rejected you from the survey?

- ◯ Yes, I am happy with my answers and wish to exit the survey
- ◯ No, I would like to go back and start over
- ◯ Please add a comment here if you would like to tell us your thoughts about the traffic or the survey before you exit.

APPENDIX C: CASE STUDY BENEFIT COST ANALYSIS

The case study estimates the benefits and costs of resolving a persistent bottleneck condition on a main commuting highway leading away from Half Moon Bay, CA that currently occurs between 7 am and 9 am each weekday with a queue length over 200 vehicles deep, with over 2,800 vehicles experiencing 220 hours of delay, daily. The analysis is based on the assumption that the bottleneck will be resolved by incentivizing enough people to travel as passengers rather than as drivers, that the queue that forms at the bottleneck will be reduced to practically nothing—and maintained at that level for 20 years. The benefit-to-cost analysis is shown in Table 25. A 20-year timeframe is used for the analysis in order to be consistent with evaluation of other alternative solutions that might be considered.

Table 25. Benefit Cost Analysis for Congestion-Clearing Payments to Passengers at Half Moon Bay

Benefit/Cost Analysis for Congestion-Clearing Payments to Passengers, Highway 92							
			3%	7%	Emissions Impact (tonnes		
Costs	Year 1	Year 2	20 yr NPV at 3%	20 yr NPV at 7%	Year 1	Year 2	20 years total
Incentives for Passengers to travel as passengers	$ 2,048,000	$ 3,716,100	$ 70,760,835	$ 47,940,413			
Incentives for passengers to travel early as passengers	$ 122,850	$ 412,832	$ 29,465,204	$ 17,859,757			
Marketing	$ 100,000	$ 100,000	$ 2,473,465	$ 1,637,968			
Administration	$ 300,000	$ 300,000	$ 7,420,356	$ 4,913,874			
Bottleneck casual carpool parking	$ 16,143,809	$ 1,200,243	$ 30,883,899	$ 25,460,166			
Total Costs	$ 18,714,659	$ 5,729,175	$ 141,003,759	$ 97,812,178			
Benefits	Year 1	Year 2	20 yr NPV at 3%	20 yr NPV at 7%			
Reduced existing congestion costs							
Vehicle Delay Reduced (morning only)	$ 624,324	$ 1,286,108	$ 23,639,479	$ 16,063,088			
Vehicle Delay Reduced (evening)	$ 312,162	$ 643,054	$ 11,819,730	$ 8,031,541			
Fuel Use Reduced (adjusted for evening)	$ 59,058	$ 120,432	$ 2,106,186	$ 1,441,635			
Emissions/Pollution Reduced (adjusted for evening)	$ 6,975	$ 14,809	$ 304,026	$ 304,026	140	285	6,887
Reduced existing trip costs							
Vehicle Miles Travelled (fuel and maintenance)	$ 2,724,352	$ 4,492,352	$ 85,783,291	$ 58,186,922			
Emissions/Pollution	$ 198,542	$ 340,227	$ 7,680,057	$ 7,680,057	3,971	6,548	174,476
Destination Parking	$ 250,400	$ 412,900	$ 7,884,494	$ 5,348,063			
Congestion Beyond Corridor	$ 2,003,200	$ 3,303,200	$ 63,075,951	$ 42,784,501			
Crash Costs	$ 716,821	$ 1,180,183	$ 22,614,586	$ 15,337,838			
Total Benefits (traditional view)	$ 6,895,835	$ 11,793,265	$ 224,907,800	$ 155,177,671	4,110	6,833	181,362
Benefit:Cost Ratio	0.37	2.06	1.60	1.59			
Other quantified benefits							
Inconvenience Cost Reduced (morning only)	$ 5,004,129	$ 9,849,771	$ 111,946,582	$ 81,636,367			
Increased economic activity							
Incentive Multiplier Impact	$ 5,483,263	$ 9,394,980	$ 176,339,514	$ 119,826,514			
Expanded Income Impact	$ 1,773,000	$ 4,035,600	$ 126,626,962	$ 81,432,971			
Total Benefits (expanded view)	$ 19,156,226	$ 35,073,617	$ 639,820,858	$ 438,073,523			
Benefit:Cost Ratio (expanded view)	1.0	6.1	4.5	4.5			
Benefits exceed costs by			$ 498,817,099				

The key case study assumptions are that:

1. Congestion-clearing payments to passengers will be implemented on the route, in a combination of

    a. payments for traveling as a passenger, and

    b. graduated payments for traveling as a passenger earlier (or later) than the peak-of-the-peak demand period;

    sufficient to clear existing congestion, respond to resulting intra-peak demand shift, and absorb growth in travel demand.

2. To facilitate passenger travel, it is anticipated a meeting-place-based carpool formation solution will be implemented with parking provision near the bottleneck location in Half Moon Bay;

3. Some form of limitation will be placed on SOV travel during the peak-of-the-peak to maximize passenger travel during that time.

The key findings are that on the basis of 20 years operation discounted at 3% the project would have a benefit cost ratio (BCR) of 1.6 using traditional valuation of transport benefits, and 4.5 using a broader valuation that captures the likely social and economic uplift that would result from solving this long-running bottleneck. Total costs in present day dollars would be in the order of $141.0 million, while total benefits would be in the order of $639.8 million, representing value creation of almost half a billion dollars. Some further perceived benefits have not been included in the analysis.

The project survey established that for this route, 50% of the commuters would be prepared to travel as passengers, if the deal is right. The other 50% would only be drivers, but of those a further 50% (25% of the total commuters) would be prepared to provide rides for passengers, again if the deal is right. Also, with the removal of congestion, an additional 985 people would begin to travel the route during the morning rush (a 41% increase in travelers).

The base case is modeled on the assumption that while just over 500 people will initially need to shift to being passengers, within a year fully 50% of all travelers will need to be passengers, and many of these will be incentivized to travel earlier (or later) than their preference in order to maintain zero congestion.

The incentive for 50% of the people to travel as passengers, based on the ‘new’ curve shown in Figure 31 (including the people who would begin to travel if congestion goes away) is $15 per day, with the qualification that traveling as a passenger must be easy.

Currently, the peak-of-the-peak travel period is from 7 am to 8 am. The initial removal of congestion by incentivizing 500 people would cause an ‘intra-peak demand shift’ in which commuters’ departure times would shift towards a more preferred, slightly later peak-of-the-peak between 8 am and 9 am. In fact, almost all travelers would prefer this later time (see Figure 32). The intra-peak demand shift would cause the queue to re-form. To prevent the queue reforming a second incentive is envisaged that would pay people traveling as passengers to travel earlier (or later).

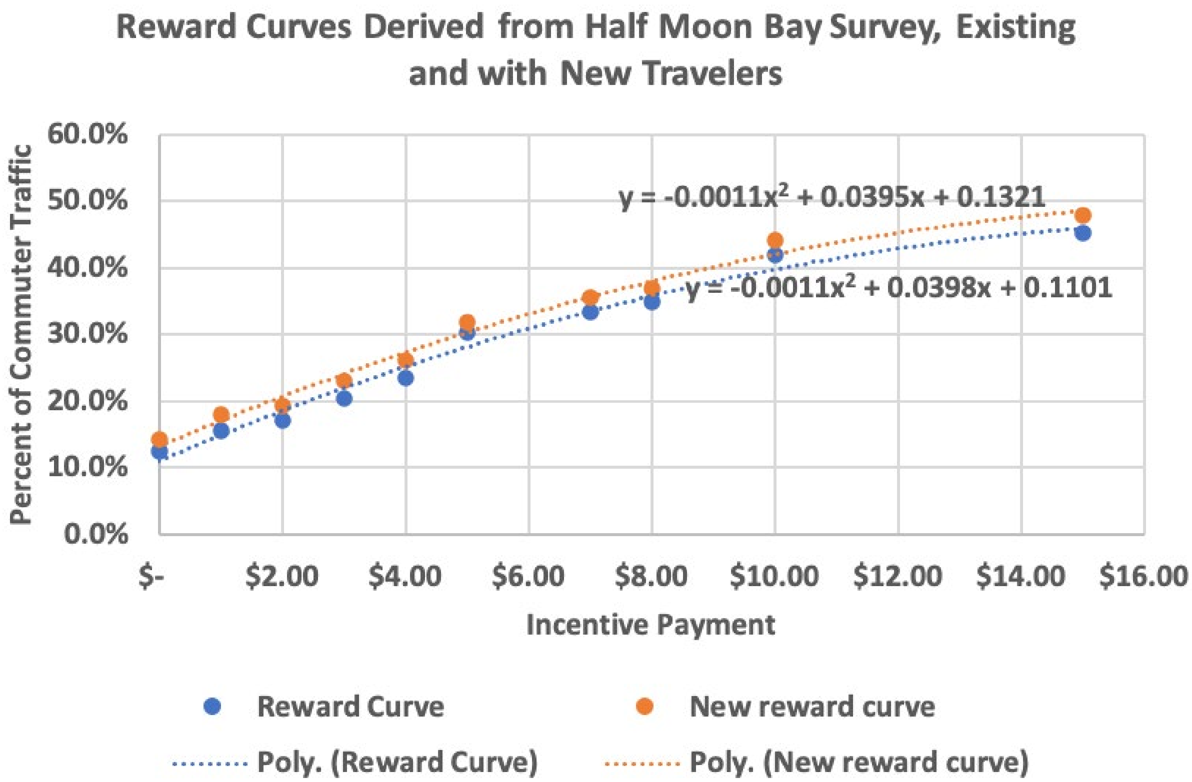

Figure 31. Incentive curves, existing and new commuters, Half Moon Bay bottleneck

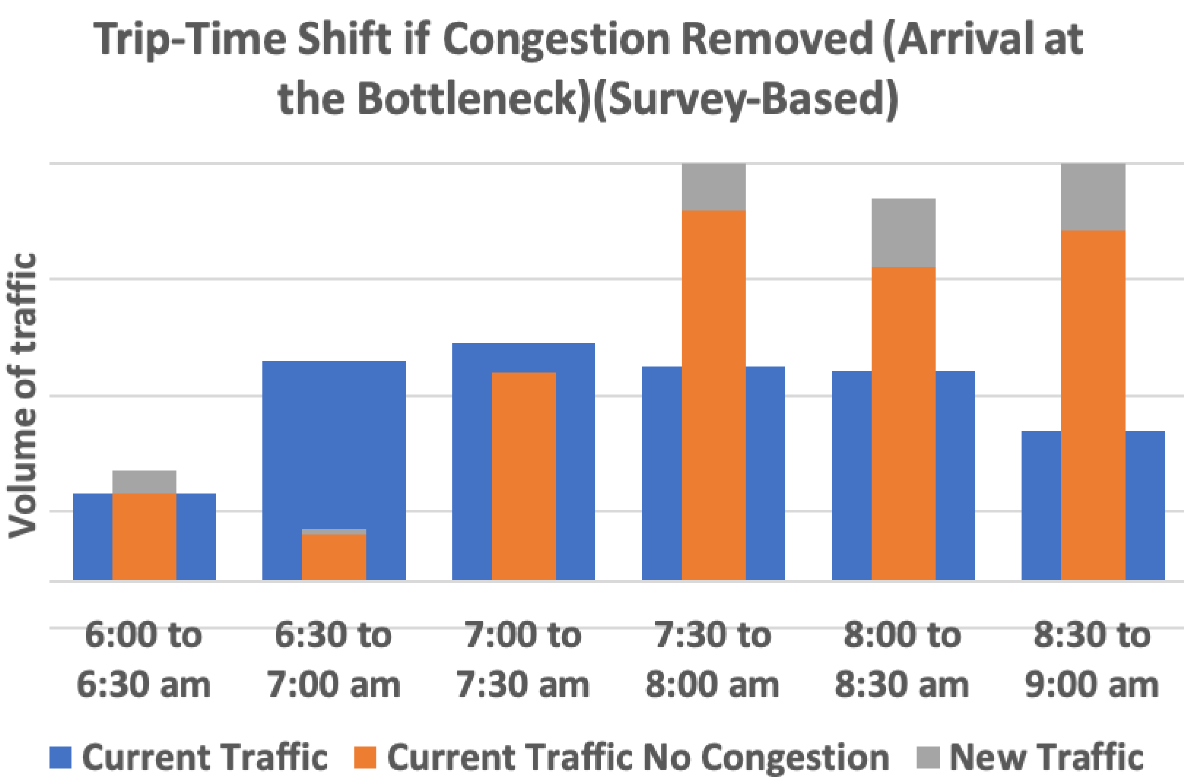

Figure 32. Case Study Intra-Peak Demand Shift

This second incentive is modeled on the basis that it is greatest for people traveling at 7 am and declines as people travel later. While modeled with a reduction every 15 minutes, it might work more smoothly in practice if it reduced every 5 minutes, or even every minute, so that bunching behavior that could be driven by the changing levels of incentive is avoided. Note that a 'Go Later Bonus' has not been modeled, though it would be appropriate and would likely reduce overall costs.

As the population grows and demand to travel increases, the number of people each year needing to be incentivized to travel as passengers, and early (or late), will increase because the goal is to keep the amount of traffic at a congestion-free level. The going-early incentive will need to be increased to include ever earlier time periods. See Figure 33. The modeling grows the going-early incentive to a high of $33 (in 2019 dollars) for passing the bottleneck as a passenger at 5:15 am in year 20. Some cost saving techniques would likely be developed by then.

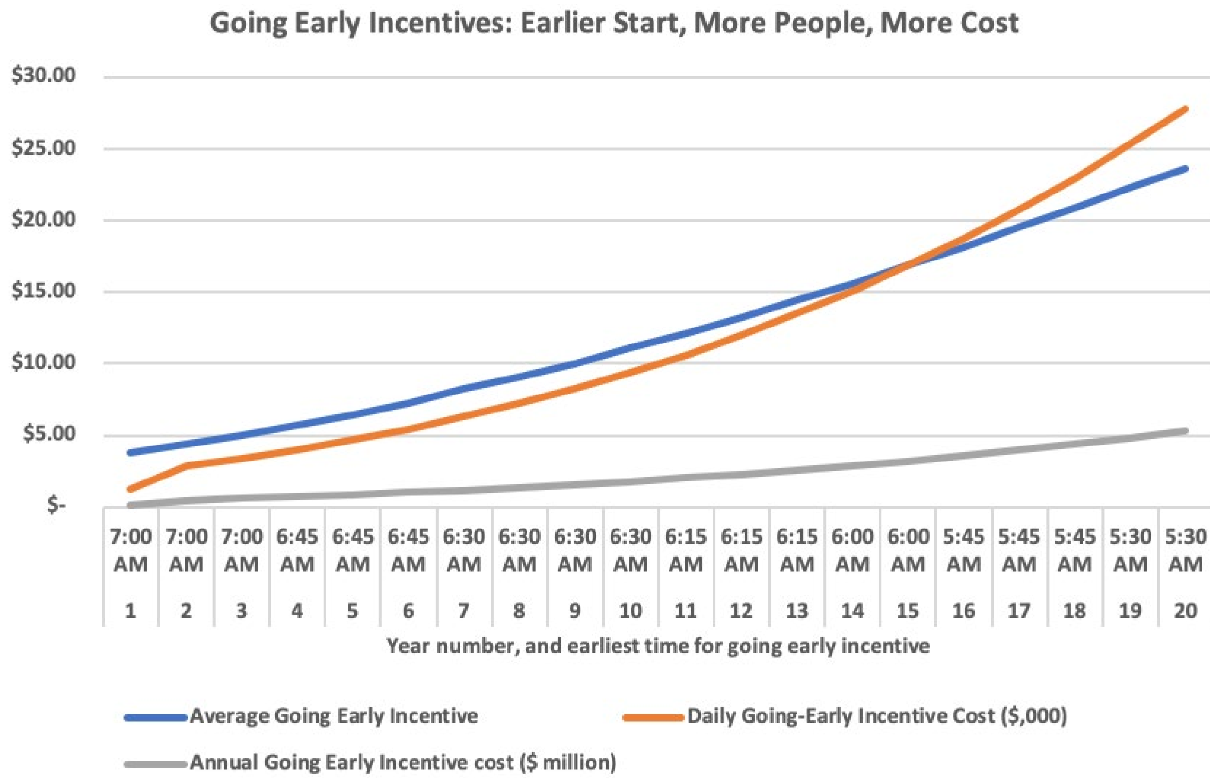

Figure 33. Going Early Incentives for Half Moon Bay bottleneck

The modeling underlying these figures also finds that the peak period is being decongested for the benefit of SOV drivers—those who would only drive, alone. As can be seen in Table 26, without a mechanism for preventing it (and such a mechanism has not been defined for the case study corridor), SOVs crowd out passenger-carrying vehicles, and passengers have to be incentivized to travel at ever earlier times to prevent a new queue forming.

A mechanism to limit SOV travel would make these projections more realistic in terms of the cost and likely success of incentives achieving the ongoing congestion removal goal. Ideas for such a mechanism include:

- the imposition of variable charges for SOVs during peak (which would provide funds to offset the costs of CCPTP);
- a HOV bypass that gives HOVs priority access to the bottleneck and forces SOVs to queue, awaiting a space in the stream of HOVs;
- a solution that allows but is limited to a fixed number of SOVs per minute.

Any such mechanism would be likely to reduce project costs because more passengers would be able to travel in the preferred peak period of 8 am to 9 am, therefore reducing the need for as much go early bonus. On the other hand, such a mechanism might incur costs for installation of control equipment and access and raise opposition to the overall project.

Table 26. Passenger Travel under Incentive Conditions without a Limitation on SOV Travel

Passengers per 15-Minute Period at End of Each Year
Note 0 Passengers Means 100% SOV Demand in Period.
Note Assumption is that All Passengers are Incentivised,
Those Traveling Before 8 am Receive Going-Early Bonus

From	To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
8:45 AM	9:00 AM	290	278	266	254	242	228	214	200	186	172	154	140	122	106	88	70	52	34	12	0
8:30 AM	8:45 AM	242	228	216	202	186	172	154	140	124	106	88	70	50	32	12	0	0	0	0	0
8:15 AM	8:30 AM	280	268	256	242	230	218	202	188	172	160	142	126	108	92	72	48	4	0	0	0
8:00 AM	8:15 AM	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7:45 AM	8:00 AM	428	416	386	360	330	298	262	230	198	160	124	88	46	6	0	0	0	0	0	0
7:30 AM	7:45 AM	490	486	480	474	470	464	458	452	446	438	432	426	418	414	366	316	266	176	76	0
7:15 AM	7:30 AM	326	316	306	294	282	272	258	246	234	220	206	192	178	162	148	128	114	96	78	28
7:00 AM	7:15 AM	86	234	390	392	384	376	366	356	348	336	328	318	306	296	284	272	260	248	234	224
6:45 AM	7:00 AM	0	0	0	156	328	444	436	432	424	418	410	402	394	386	376	368	360	350	342	330
6:30 AM	6:45 AM	0	0	0	0	0	60	264	456	588	586	584	582	580	578	574	572	570	568	566	564
6:15 AM	6:30 AM	0	0	0	0	0	0	0	0	68	284	506	582	580	578	574	572	570	568	566	564
6:00 AM	6:15 AM	0	0	0	0	0	0	0	0	0	0	0	146	390	578	574	572	570	568	566	564
5:45 AM	6:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	48	314	576	610	610	608	606
5:30 AM	5:45 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	232	508	608	606
5:15 AM	5:30 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	486
5:00 AM	5:15 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5:00 AM	9:00 AM	2157	2228	2303	2378	2457	2538	2621	2708	2797	2890	2985	3084	3185	3290	3397	3510	3625	3744	3867	3992

Note that the total number of passengers increases each year, while total number of drivers (combined drive alone and with passengers) increases by the same amount.

Base Case Assumptions

Table 27 shows the base-case values and sources for all assumptions in the benefit cost analysis shown in Table 25.

Table 27. Assumptions and Values for Modeling Benefits and Costs

Assumption Name	Description/Rationale	Base Case Value	Source
Days per year	Days per year that incentives are needed on this route. It is perceived that some weekdays through the year do not require incentives to avoid a queue at the bottleneck. Days not needing incentives include statutory holidays and school holidays.	200	Project team estimate
Value of time for travelers' delay	The fair rate per hour to allow for delay time, for people who are currently delayed by the bottleneck. The 2019 Urban Mobility Report (TTI and Inrix) uses "*the median hourly wage rate for all occupations as produced by the Bureau of Labor Statistics (1) as a base*"—which is $18.12 (2017 dollars) and $18.98 (2019 dollars). This rate will be far lower than the median hourly wage rate for people who are subject to this bottleneck, which the project team estimates to be on the order of $35 per hour. The survey asked household income rather than individual income. The median household income for the catchment (per ACS) is $124,159, and per the survey is $121,862 based on the lower parameter of each bracket, and $166,277 based on the upper. Allowing that two people per household are earning, this calculation would deliver an average income per person of between $62,000 and $83,000. At 2000 hours per year this comes to $31 to $41.50 per hour. This has been adjusted by the project team for reasonableness.	$25	Project team calculation

Assumption Name	Description/Rationale	Base Case Value	Source
Value of Time for travelers' reduced inconvenience	88% of the traveling population (in the sample) travel at a time that is different to their preferred time: either earlier or later. Removing congestion theoretically makes it possible for them to travel at their preferred time. Certainly, if congestion is removed, they will travel at a time that is more to their liking. This benefit is not usually modeled in transportation analysis, but for the purpose of congestion-clearing payments to passengers is clearly an important benefit, providing either additional time spent before leaving home in the morning, or additional time arrived at the destination. Because there is no conventional wisdom or method for valuing this 'reduction of inconvenience', the project team proposes that it should be at the same value of time that is used to value delay.	$25	Project team assertion
Value of Time for commercial travel saved	Non-commuter travel is a component of the traffic caught up in delay at the bottleneck. The Urban Mobility Report uses $52.14 ($2017) for this factor, $54.59 (2019 dollars)	$54.59	TTI Report
Proportion of delay reduction that happens in first year	At the start of the first year there will still be congestion and delay. By the end of the year there will be no delay. For simplicity of modeling the reduction in the amount of delay, it is assumed this reduction occurs as a gradual transition through the year. Hence the adjustment to the full delay reduction for reasonableness.	50%	Project team estimate
Proportion of existing 7–9 am traffic that is commercial	The value of delay is calculated as the weighted average of the delayed traffic value of time: percent that is commercial times the commercial rate and percent that is personal times the personal rate	10%	Verbal estimate by HMB Engineer
Ratio of evening delay to morning delay	It is reasonable to expect that reducing the morning traffic (and delay) will reduce the evening traffic (and delay). However, the focus of the project was on managing the morning congestion, so no specific data have been collected on the existing shape of the evening traffic or estimates of how it will change as a result of CCPTP. Therefore, a reasonable allowance is used, based on the morning delay reduction.	50%	Project team estimate/ judgement
Ratio of actual to perceived value of a lottery entry	It is expected that incentives will be offered at a cash value, that can be converted into lottery entries, as a cost-reducing strategy – because the value of a lottery entry is generally valued at double its actual value. The survey did not explore the expectations that would be held by respondents in this regard, so an estimate has to be used.	60%	Project team estimate

Assumption Name	Description/Rationale	Base Case Value	Source
Population Growth rate, annually, current	The population of people aged 16+ in the catchment of the bottleneck has been growing at 3.27% average for the past five years. While there is a growth limitation of 1% within the Half Moon Bay City limits, and the actual growth rate of HMB City is 2%, it is clear that the rural areas have been growing more quickly.	3.27%	Project team sees no reason for this average to fall.
Commercial traffic growth rate, annual	The project has no information about the amount of commercial traffic nor how it is changing over time, except the estimate that it is 10% of morning traffic provided by the City Engineer.	3%	Project team estimate
Starting number of commercial vehicles 7–9 am	The commercial vehicle counts modeled on the survey data and the historical counts of vehicle throughput at and beyond the bottleneck, and the assumption from the HMB Engineer that current commercial vehicle make up 10%.	271	10% of current throughput.
Proportion of population who would travel 7–9 am if there was no traffic	The survey exposed a number of people who would start to travel if there was no congestion. These should be added to the people who already travel. The total of these people divided by the current population is the proportion of people who would travel. In the modeling this ratio is assumed to be a constant proportion that would travel as the population grows over time.	15.46%	Calculated based on the results of the survey and the estimated population at the end of 2019.
Maximum 2-hour vehicles: start	In order to calculate the number of people who are needed to travel as passengers, it is necessary to determine the maximum number of vehicles that can depart during the peak period. Based on historical records this flow is assumed to be 1,300 per hour, or 2,600 through the morning 2-hour peak.	2600	Historic traffic flow data from Caltrans
Starting incentive level per passenger per day	The initial proportion of people who are needed to travel as passengers, as a percentage of all commuters, delivers a price for rewards on the reward curve. The starting percentage is 35% and the starting price is $5. This assumption pre-supposes that switching to passenger travel is easy to do.	$5	Set by the team based on survey results, converted to a reward curve.
First discount factor, and second discount factor	USDOT advice for benefit cost analysis suggests the use of two different discount factors to apply over 20 years: 3%, and 7%. These would usually be the actual cost of capital but comparing on a consistent basis makes it easier to compare between different projects. 3% is used for discounting carbon emissions reduction values.	3%, 7%	USDOT Guidance.[86]

Assumption Name	Description/Rationale	Base Case Value	Source
Starting number of passengers as a target for incentive	The initial offer needs to be made to the estimated current excess traffic, the number of vehicles that if removed across the morning peak would get rid of delay. The target level is calculated in the model based on the survey. In a real implementation it should be based on actual delay and varying queue length observed on the ground.	514	The modeled result from the survey.
Catchment population: starting	The population of 16+ people in the catchment—that will grow by the population growth factor.	27,003	Most recent population report plus growth estimate in current year.
Current delay in minutes per day	The value of delay that will be reduced is based on the starting level of delay. This number of minutes of daily delay should be determined by observing the actual queueing activity on the ground. For the case study it was based on modeling based on the survey	13,213	The modeled result from the survey
Percent of fleet with stop–start control	Stop-start control allows a car to not idle when not moving. The car automatically shuts off when stopped, and automatically starts when the driver presses the accelerator. This fraction has an impact on the amount of fuel use and emissions from idling caused by delay. This factor is incremented annually for increasing penetration of the technology.	5.1%	Derived from data in the 2018 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975.[87]
Minimum proportion of commuters who are drivers	People divide up into three groups: those who are prepared on some basis to travel as passengers, and those who will only drive, with the latter divided into those who would take passengers and those who would not. These proportions provide a limit on the amount of traffic reduction that is possible. Used to allocate total travelers into passengers and drivers to determine the amount of incentive required each year.	50%	Based on the survey.
Current year value of a metric ton of CO_2	USDOT BCA guidance provides the socialized cost of carbon in $2015. These can be converted to the current year for calculating the value of emissions reduced.	$50	USDOT BCA analysis guidance[88]
Number of people adjusting to going early, year 1	This quantity is the starting assumption for how many people adjust to going early. This quantity grows based on the modeling growth for population and travelers. The incentive is paid to these people and those who are already traveling early. These people are removed from the calculation of convenience benefit.	431	Project team calculation based on survey and modeling

Assumption Name	Description/Rationale	Base Case Value	Source
Go-early bonus per increment of 15 minutes	This monetary amount is the rate at which each additional 15 minutes early is paid as an incentive to convince passengers to travel earlier. The hourly rate is 4 times this amount.	$3.00	Project team calculation based on assumption of $12 for going 1 hour early, $9 for going 45 minutes early, $6 for going 30 minutes early, and $3 for going 15 minutes early. All are designed to shift travel volume from the peak-of-the-peak. With the peak-of-the-peak being 8 am to 9 am (based on the survey, the desired peak not the actual current peak), going an hour early means, all people who travel as a passenger from 7 am to 7:15 am would receive the $12 incentive.
Percent of passengers arriving at bottleneck needing to park	The meeting-place-based protocol for carpool formation (or vanpool, or bus for that matter) works most easily if there is a parking space (a park and ride) near the bottleneck. Some proportion of people will choose to drive to the meeting place. Provision of parking enables the best concentration of people going to common destinations and reduces complexity for the return journey. However, it also imposes a cost on the solution: the need to provide parking. It is necessary to estimate the proportion of people arriving as drivers wishing to park and be passengers to arrive at a realistic estimate of the size of parking to provide.	75%	Project team estimate. Allows for some people who might walk, cycle, catch a shuttle, or get dropped off rather than driving to park. Note that the model doesn't include a charge for parking, but that a charge or other mechanism might be needed to reduce demand for this parking.
Cost per parking space to develop at-grade parking (in addition to land cost)	Builds on the previous item	$5,563	Per Coffell et al., 2012, midpoint of range given, updated to 2019 dollars
Cost per square foot for land near the bottleneck	Builds on the previous item	$15	Per real-estate advertisement, November 2019
Area in square feet per parking space at grade	Builds on the previous item	350	Per Coffell et al., 2012[89]

Assumption Name	Description/Rationale	Base Case Value	Source
Annual operating cost for parking, per space	Builds on the previous item	$135	Per Coffell et al., 2012, midpoint of range given, updated to 2019 dollars
Initial year cost for marketing	An allowance for effective marketing of the solution to the local population who might use it. Note that this solution needs the involvement of everyone who uses the route during the weekday morning rush.	$100,000	Project team estimate. Note that the cost for marketing is kept the same for the second year, and then grows in proportion to the total value of incentives being paid out each year.
Initial year cost for administration	An allowance for effective administration of the solution, including customer service, the app, audit, all aspects of operations, and ongoing reporting and research into methods for minimizing incentive cost.	$300,000	Project team estimate. Note that the cost for administration is kept the same for the second year, and then grows in proportion to the total value of incentives being paid out each year.
Monetized value of crash avoided	An important benefit of the project will be the reduction of vehicle miles driven, which can be expected to reduce the rate of crashes. This item relates to the weighted average value of a crash of undetermined severity. It will be applied against the total vehicle miles traveled reduction due to people traveling as passengers instead of as drivers.	$139,805	USDOT rate for 2015, adjusted to 2019 dollars, it is the probability of each type of crash severity times the monetization rate for each type of crash severity, except fatality.[90]
Monetized value of a fatality avoided	As for above, but for fatalities rather than just crashes	$10,399,968	As for above, but for fatalities rather than just crashes.
Probability of a fatality, per 100 million vehicle miles traveled	Statistically speaking, a fatality will occur with some level of predictability based on accumulated vehicle miles traveled.	0.598	SWITRS statistics, focused on San Mateo County. Avoided miles will be across a variety of routes and destinations county-wide. While some might venture into other counties, the vast majority will be in San Mateo County.
Probability of a serious injury crash per 100 million vehicle miles traveled	As above, but for injury crashes.	2.681	As above. Note that the statistic from SWITRS is for 'serious injury crashes,' while the monetization value above is for all crashes.

Assumption Name	Description/Rationale	Base Case Value	Source
Rate of growth of delay if there is no solution	Assuming that nothing is implemented to reduce delay, it is reasonable to expect that delay will grow, even at a saturated location such as the focus of the case study, because population and business grows.	3%	Project team estimate. It is aligned with the assumption of the rate of population and commercial activity growth.
Percent of new commuters going to work (as opposed to other trip purposes)	The survey established that a significant number of people who are not currently traveling would be likely to start traveling if the congestion was defeated. The majoring of these people would be heading to jobs in other parts of the county. This increment in employment of people living on the Coastside is a benefit that flows from the solution.	75%	Project team estimate
Attribution of benefit per new worker from above	The challenge is to know how much to attribute to the solution, for the increase in employment of people living on the Coastside.	$4,800	The project team considers it reasonable to attribute one hour of earnings per day, 240 days per year, at the national median hourly rate, which is approximately $20.
New commuters, first year	The survey finds that a number of people would start to travel if the congestion was defeated. Most of these people would travel for employment. This number is incremented by commuter growth each year.	985	Project team calculation based on survey and model
Average one-way trip miles for people traveling in current morning rush	For calculation of VMT avoided by people traveling as passengers rather than as drivers. This mileage is the distance from the bottleneck to the destination.	21.76 miles	Project team calculation based on survey
Average cost of fuel and maintenance per vehicle mile	Estimate of cash costs that commuters will avoid when stopping driving and starting to travel as a passenger.	$0.25	Project team allowance based on averages accessed via the internet.
Value per day of parking spaces not used at destinations	The vast majority of people driving past the bottleneck do not pay for parking at their destination. A reduction in demand for destination parking would result in savings to someone, either by avoiding adding parking, or by reducing the amount of free parking provided. This assumed allowance is probably well below the actual cost.	$1.00	Project team allowance.

Assumption Name	Description/Rationale	Base Case Value	Source
Value per day of vehicle-round-trip travel beyond the corridor	Each vehicle trip from the Coastside puts demand on the infrastructure of San Mateo County. The County recently provided an incentive of $8 per vehicle-round-trip reduced for people who carpool. It is assumed that this dollar amount is a fair assessment of the value to the County of having fewer vehicles from the Coastside.	$8.00	Sourced from C/CAG, the project team feels this amount of money is a reasonable allowance. It is noted that the current payment amount is lower than $8, but also that far fewer people are participating as a result.
Multiplier effect on local economy of each $1 cash gain	Several of the benefits from the congestion-clearing payments to passengers project will be felt in cash terms in the hands of the people who live on the Coastside. This additional disposable income in the hands of residents can be reasonably expected to be spent in the community, thereby generating an economic uplift. There are many opinions of the extent of such an uplift in the literature. Note that the calculation of the benefit doesn't include the incentives themselves, because it is assumed that the local people will pay for the program. It is likely a pilot project would return different values.	1.25	Project team assumption. For each dollar gained, an additional $1.25 will be generated through the local economy.

Sensitivity Analysis

Table 28 shows the changes in the present value of 20-year costs and benefits and resulting BCR in 2019 dollars discounted at 3%, under variations of the key assumptions by 5% each.

Table 28. Sensitivity Analysis, Impact of Adjusting Factors by 5%

Factor	Base Case Value	New Value	Change	PV 20-yr Costs in $2019 at 3% discount rate, $million	Change from Base Case Costs, $million	PV 20-yr Benefits in $2019 at 3% discount rate, $million	Change from Base Case Benefits, $million	PV 20-yr BCR	Change from Base Case BCR
Base Case	0	0	0	$ 141.0	0	$ 639.8	0	4.5	0
Proportion of population who commute	15.46%	16.23%	4.98%	$ 150.3	$ 9.3	$ 657.0	$ 17.2	4.4	-0.1
Required rate of incentives based on the reward curve, per passenger day	$ 15.00	15.75	5.00%	$ 144.4	$ 3.4	$ 639.9	$ 0.1	4.4	-0.1
Cost savings from passengers taking lottery entries instead of cash (value is expected average discount to value perceived by passengers)	40%	38%	-5.00%	$ 144.3	$ 3.3	$ 639.8	$ -	4.4	-0.1
Required go-early bonus per hour prorated	$ 12.00	$ 12.60	5.00%	$ 142.6	$ 1.6	$ 639.7	$ (0.1)	4.5	0
Value of time for commuters	$ 25.00	$ 23.75	-5.00%	$ 141.0	$ -	$ 632.8	$ (7.0)	4.5	0
Growth in non-commuter traffic	3%	3.15%	5.00%	$ 141.0	$ -	$ 638.6	$ (1.2)	4.5	0
Starting level of people to switch to being passengers	514	540	5.06%	$ 141.0	$ -	$ 639.9	$ 0.1	4.5	0
Current level of delay in minutes per day	13,213	13,874	5.00%	$ 141.0	$ -	$ 641.8	$ 2.0	4.6	0.1
Starting level of non-commuter traffic	271	285	5.17%	$ 140.7	$ (0.3)	$ 635.3	$ (4.5)	4.5	0
Rate of population growth	3.27%	3.11%	-4.89%	$ 136.9	$ (4.1)	$ 630.8	$ (9.0)	4.6	0.1
Drive alone percent of total commuters	25%	23.75%	-5.00%	$ 136.1	$ (4.9)	$ 642.1	$ 2.3	4.7	0.2
Number of days per year passengers are incentivized	200	190	-5.00%	$ 136.0	$ (5.0)	$ 613.6	$ (26.2)	4.5	0
Rate of bottleneck departure in vehicles per hour	1,300	1,365	5.00%	$ 135.9	$ (5.1)	$ 637.3	$ (2.5)	4.7	0.2

In a worst-case scenario, for this solution to deliver no net benefit over 20 years (a BCR of 1.0), the required incentive rate would need to be more than five times the level included in the base case.

Individual Benefit and Cost Tables

The following pages show the 20-year estimates of cost and benefit that support the base case shown in Table 25.

Table 29. Estimated Costs of Incentive to Travel as a Passenger Half Moon Bay Bottleneck

					3%	7%
	Annual Passengers	Incentive (Cost) Start	Incentive (Cost) End	Incentive Cost In Dollars of Year	Incentive cost in present value	Incentive cost in present value
Year 01	250,400	$ 5.00	$ 9.00	$ 2,048,000	$ 1,988,350	$ 1,914,019
Year 02	412,900	$ 9.00	$ 9.00	$ 3,716,100	$ 3,502,781	$ 3,245,786
Year 03	443,300	$ 9.00	$ 9.00	$ 3,989,700	$ 3,651,141	$ 3,256,784
Year 04	442,200	$ 9.00	$ 9.00	$ 3,979,800	$ 3,536,001	$ 3,036,170
Year 05	442,000	$ 9.00	$ 9.00	$ 3,978,000	$ 3,431,458	$ 2,836,259
Year 06	475,400	$ 9.00	$ 9.00	$ 4,278,600	$ 3,583,260	$ 2,851,012
Year 07	477,400	$ 9.00	$ 9.00	$ 4,296,600	$ 3,493,529	$ 2,675,707
Year 08	480,500	$ 9.00	$ 9.00	$ 4,324,500	$ 3,413,800	$ 2,516,898
Year 09	517,300	$ 9.00	$ 9.00	$ 4,655,700	$ 3,568,206	$ 2,532,392
Year 10	555,300	$ 9.00	$ 9.00	$ 4,997,700	$ 3,718,758	$ 2,540,577
Year 11	562,000	$ 9.00	$ 9.00	$ 5,058,000	$ 3,654,007	$ 2,403,019
Year 12	570,000	$ 9.00	$ 9.00	$ 5,130,000	$ 3,598,079	$ 2,277,781
Year 13	611,900	$ 9.00	$ 9.00	$ 5,507,100	$ 3,750,067	$ 2,285,251
Year 14	622,600	$ 9.00	$ 9.00	$ 5,603,400	$ 3,704,508	$ 2,173,095
Year 15	634,600	$ 9.00	$ 9.00	$ 5,711,400	$ 3,665,930	$ 2,070,074
Year 16	648,200	$ 9.00	$ 9.00	$ 5,833,800	$ 3,635,431	$ 1,976,110
Year 17	663,300	$ 9.00	$ 9.00	$ 5,969,700	$ 3,611,767	$ 1,889,854
Year 18	712,300	$ 9.00	$ 9.00	$ 6,410,700	$ 3,765,611	$ 1,896,695
Year 19	730,500	$ 9.00	$ 9.00	$ 6,574,500	$ 3,749,345	$ 1,817,904
Year 20	750,300	$ 9.00	$ 9.00	$ 6,752,700	$ 3,738,806	$ 1,745,026
					$ 70,760,835	$ 47,940,413

Table 30. Estimated Costs of Incentives for Passengers to Go Early, Half Moon Bay Bottleneck

			60%		3%	7%
	Going Early Bonus Earners (midpoint) (excludes drivers)	Average Going Early bonus value	Going Early Bonus Cost Daily (End)	Going Early Bonus Annual	Going Early cost in present value	Going Early cost in present value
Year 01	539	$ 3.80	$ 1,229	$ 122,850	$ 119,272	$ 114,813
Year 02	1,096	$ 4.41	$ 2,900	$ 412,832	$ 389,134	$ 360,584
Year 03	1,132	$ 4.99	$ 3,388	$ 628,755	$ 575,400	$ 513,252
Year 04	1,169	$ 5.73	$ 4,022	$ 741,000	$ 658,369	$ 565,305
Year 05	1,207	$ 6.47	$ 4,689	$ 871,125	$ 751,440	$ 621,100
Year 06	1,246	$ 7.26	$ 5,426	$ 1,011,529	$ 847,140	$ 674,024
Year 07	1,287	$ 8.24	$ 6,363	$ 1,178,942	$ 958,588	$ 734,186
Year 08	1,329	$ 9.10	$ 7,258	$ 1,362,123	$ 1,075,272	$ 792,768
Year 09	1,372	$ 10.02	$ 8,245	$ 1,550,310	$ 1,188,184	$ 843,266
Year 10	1,417	$ 11.08	$ 9,418	$ 1,766,273	$ 1,314,273	$ 897,884
Year 11	1,464	$ 12.12	$ 10,645	$ 2,006,309	$ 1,449,401	$ 953,183
Year 12	1,512	$ 13.21	$ 11,989	$ 2,263,386	$ 1,587,494	$ 1,004,971
Year 13	1,561	$ 14.44	$ 13,526	$ 2,551,488	$ 1,737,439	$ 1,058,777
Year 14	1,612	$ 15.57	$ 15,061	$ 2,858,706	$ 1,889,941	$ 1,108,655
Year 15	1,665	$ 16.92	$ 16,901	$ 3,196,157	$ 2,051,491	$ 1,158,434
Year 16	1,719	$ 18.15	$ 18,721	$ 3,562,194	$ 2,219,842	$ 1,206,638
Year 17	1,776	$ 19.53	$ 20,816	$ 3,953,747	$ 2,392,082	$ 1,251,655
Year 18	1,834	$ 20.84	$ 22,929	$ 4,374,584	$ 2,569,607	$ 1,294,282
Year 19	1,894	$ 22.28	$ 25,323	$ 4,825,213	$ 2,751,752	$ 1,334,212
Year 20	1,955	$ 23.67	$ 27,760	$ 5,308,311	$ 2,939,083	$ 1,371,768
					$ 29,465,204	$ 17,859,757

Table 31. Estimated Marketing Cost for Communicating Incentives Solution for Half Moon Bay Bottleneck

	Marketing			$ 100,000	3%	7%
Year	Passenger incentives	Going early incentives	Total	Marketing	Marketing at present value	Marketing at present value
1	$ 2,048,000	$ 122,850	$ 2,170,850	$ 100,000	$ 97,087	$ 93,458
2	$ 3,716,100	$ 412,832	$ 4,128,932	$ 100,000	$ 94,260	$ 87,344
3	$ 3,989,700	$ 628,755	$ 4,618,455	$ 111,856	$ 102,364	$ 91,308
4	$ 3,979,800	$ 741,000	$ 4,720,800	$ 114,335	$ 101,585	$ 87,226
5	$ 3,978,000	$ 871,125	$ 4,849,125	$ 117,443	$ 101,307	$ 83,735
6	$ 4,278,600	$ 1,011,529	$ 5,290,129	$ 128,124	$ 107,302	$ 85,374
7	$ 4,296,600	$ 1,178,942	$ 5,475,542	$ 132,615	$ 107,828	$ 82,586
8	$ 4,324,500	$ 1,362,123	$ 5,686,623	$ 137,727	$ 108,723	$ 80,158
9	$ 4,655,700	$ 1,550,310	$ 6,206,010	$ 150,306	$ 115,197	$ 81,757
10	$ 4,997,700	$ 1,766,273	$ 6,763,973	$ 163,820	$ 121,897	$ 83,278
11	$ 5,058,000	$ 2,006,309	$ 7,064,309	$ 171,094	$ 123,602	$ 81,286
12	$ 5,130,000	$ 2,263,386	$ 7,393,386	$ 179,064	$ 125,592	$ 79,507
13	$ 5,507,100	$ 2,551,488	$ 8,058,588	$ 195,175	$ 132,905	$ 80,991
14	$ 5,603,400	$ 2,858,706	$ 8,462,106	$ 204,948	$ 135,495	$ 79,482
15	$ 5,711,400	$ 3,196,157	$ 8,907,557	$ 215,737	$ 138,473	$ 78,193
16	$ 5,833,800	$ 3,562,194	$ 9,395,994	$ 227,567	$ 141,812	$ 77,085
17	$ 5,969,700	$ 3,953,747	$ 9,923,447	$ 240,342	$ 145,411	$ 76,086
18	$ 6,410,700	$ 4,374,584	$ 10,785,284	$ 261,215	$ 153,436	$ 77,284
19	$ 6,574,500	$ 4,825,213	$ 11,399,713	$ 276,096	$ 157,454	$ 76,343
20	$ 6,752,700	$ 5,308,311	$ 12,061,011	$ 292,112	$ 161,735	$ 75,487
					$ 2,473,465	$ 1,637,968

Table 32. Estimated Administration Costs for Operation of Incentives Solution for Half Moon Bay Bottleneck

	Administration	$ 300,000	3%	7%
Year	Total Incentives being paid out	Administration	Administration at present value	Administration at present value
1	$ 2,170,850	$ 300,000	$ 291,262	$ 280,374
2	$ 4,128,932	$ 300,000	$ 282,779	$ 262,032
3	$ 4,618,455	$ 335,568	$ 307,092	$ 273,923
4	$ 4,720,800	$ 343,004	$ 304,755	$ 261,676
5	$ 4,849,125	$ 352,328	$ 303,921	$ 251,205
6	$ 5,290,129	$ 384,370	$ 321,904	$ 256,122
7	$ 5,475,542	$ 397,842	$ 323,482	$ 247,756
8	$ 5,686,623	$ 413,179	$ 326,167	$ 240,474
9	$ 6,206,010	$ 450,917	$ 345,590	$ 245,269
10	$ 6,763,973	$ 491,457	$ 365,690	$ 249,832
11	$ 7,064,309	$ 513,279	$ 370,804	$ 243,855
12	$ 7,393,386	$ 537,189	$ 376,774	$ 238,518
13	$ 8,058,588	$ 585,521	$ 398,711	$ 242,970
14	$ 8,462,106	$ 614,840	$ 406,482	$ 238,446
15	$ 8,907,557	$ 647,206	$ 415,417	$ 234,577
16	$ 9,395,994	$ 682,695	$ 425,433	$ 231,252
17	$ 9,923,447	$ 721,019	$ 436,228	$ 228,256
18	$ 10,785,284	$ 783,638	$ 460,305	$ 231,850
19	$ 11,399,713	$ 828,281	$ 472,357	$ 229,027
20	$ 12,061,011	$ 876,330	$ 485,203	$ 226,460
			$ 7,420,356	$ 4,913,874

Table 33. Estimated Cost of Providing Park and Ride Capacity Near Bottleneck

				$15	per square foot for land			
				350.00	square feet per space			
		75%		$ 5,563	$ 135		3%	7%
Year	People traveling as passengers (year end)	Passengers arriving at bottleneck by car, needing parking space	Spaces	Annual capital spend on parking facilities	Annual spend on operations	Total annual spend	Present value of capital spend on parking facilities	Present value of capital spend on parking facilities
1	1,990	1,493	1,493	$ 16,143,809	$ 201,555	$ 16,345,364	$ 15,869,285	$ 15,276,041
2	2,139	1,604	1,604	$ 1,200,243	$ 216,540	$ 1,416,783	$ 1,335,454	$ 1,237,473
3	2,294	1,721	1,721	$ 1,265,121	$ 232,335	$ 1,497,456	$ 1,370,384	$ 1,222,370
4	2,128	1,596	1,721	$ -	$ 232,335	$ 232,335	$ 206,427	$ 177,247
5	2,292	1,719	1,721	$ -	$ 232,335	$ 232,335	$ 200,414	$ 165,652
6	2,462	1,847	1,847	$ 1,362,438	$ 249,345	$ 1,611,783	$ 1,349,843	$ 1,073,999
7	2,312	1,734	1,847	$ -	$ 249,345	$ 249,345	$ 202,740	$ 155,280
8	2,493	1,870	1,870	$ 248,699	$ 252,450	$ 501,149	$ 395,612	$ 291,673
9	2,680	2,010	2,010	$ 1,513,820	$ 271,350	$ 1,785,170	$ 1,368,184	$ 971,014
10	2,873	2,155	2,155	$ 1,567,885	$ 290,925	$ 1,858,810	$ 1,383,129	$ 944,925
11	2,747	2,060	2,155	$ -	$ 290,925	$ 290,925	$ 210,170	$ 138,216
12	2,953	2,215	2,215	$ 648,780	$ 299,025	$ 947,805	$ 664,771	$ 420,837
13	3,166	2,375	2,375	$ 1,730,080	$ 320,625	$ 2,050,705	$ 1,396,430	$ 850,970
14	3,060	2,295	2,375	$ -	$ 320,625	$ 320,625	$ 211,971	$ 124,344
15	3,286	2,465	2,465	$ 973,170	$ 332,775	$ 1,305,945	$ 838,236	$ 473,335
16	3,196	2,397	2,465	$ -	$ 332,775	$ 332,775	$ 207,374	$ 112,722
17	3,437	2,578	2,578	$ 1,221,869	$ 348,030	$ 1,569,899	$ 949,815	$ 496,990
18	3,686	2,765	2,765	$ 2,022,031	$ 373,275	$ 2,395,306	$ 1,406,990	$ 708,685
19	3,619	2,714	2,765	$ -	$ 373,275	$ 373,275	$ 212,874	$ 103,214
20	3,884	2,913	2,913	$ 1,600,324	$ 393,255	$ 1,993,579	$ 1,103,796	$ 515,179
							$ 30,883,899	$ 25,460,166

Table 34. Estimated Value of Morning Delay Avoided by Implementation of Congestion Clearing Solution at Half Moon Bay Bottleneck

Morning Delay										
				1st year	Change Nothing			Implement Solution		
		3%		50%		3%			3%	7%
Year	Starting daily hours of delay	Growth in delay in year	Ending daily hours of delay	Average daily hours of delay	Cost of Annual Delay, start	Growth in delay in year	Cost of Annual Delay, end	Cost of delay avoided	Delay cost in present value	Delay Cost in present value
1	220	6.6	226.6	111.65	$1,230,196	$36,906	$1,267,102	$624,324	$ 606,140	$ 583,481
2	226.6	6.8	233.4	230	$1,267,102	$38,013	$1,305,115	$1,286,108	$ 1,212,281	$ 1,123,337
3	233.4	7	240.4	236.9	$1,305,115	$39,153	$1,344,268	$1,324,692	$ 1,212,281	$ 1,081,343
4	240.4	7.2	247.6	244	$1,344,268	$40,328	$1,384,596	$1,364,432	$ 1,212,281	$ 1,040,919
5	247.6	7.4	255	251.3	$1,384,596	$41,538	$1,426,134	$1,405,365	$ 1,212,281	$ 1,002,006
6	255	7.7	262.7	258.85	$1,426,134	$42,784	$1,468,918	$1,447,526	$ 1,212,281	$ 964,548
7	262.7	7.9	270.6	266.65	$1,468,918	$44,068	$1,512,986	$1,490,952	$ 1,212,281	$ 928,490
8	270.6	8.1	278.7	274.65	$1,512,986	$45,390	$1,558,375	$1,535,681	$ 1,212,281	$ 893,780
9	278.7	8.4	287.1	282.9	$1,558,375	$46,751	$1,605,127	$1,581,751	$ 1,212,281	$ 860,368
10	287.1	8.6	295.7	291.4	$1,605,127	$48,154	$1,653,281	$1,629,204	$ 1,212,281	$ 828,205
11	295.7	8.9	304.6	300.15	$1,653,281	$49,598	$1,702,879	$1,678,080	$ 1,212,281	$ 797,244
12	304.6	9.1	313.7	309.15	$1,702,879	$51,086	$1,753,965	$1,728,422	$ 1,212,281	$ 767,440
13	313.7	9.4	323.1	318.4	$1,753,965	$52,619	$1,806,584	$1,780,275	$ 1,212,281	$ 738,751
14	323.1	9.7	332.8	327.95	$1,806,584	$54,198	$1,860,782	$1,833,683	$ 1,212,281	$ 711,134
15	332.8	10	342.8	337.8	$1,860,782	$55,823	$1,916,605	$1,888,694	$ 1,212,281	$ 684,549
16	342.8	10.3	353.1	347.95	$1,916,605	$57,498	$1,974,103	$1,945,354	$ 1,212,281	$ 658,959
17	353.1	10.6	363.7	358.4	$1,974,103	$59,223	$2,033,327	$2,003,715	$ 1,212,281	$ 634,325
18	363.7	10.9	374.6	369.15	$2,033,327	$61,000	$2,094,326	$2,063,826	$ 1,212,281	$ 610,612
19	374.6	11.2	385.8	380.2	$2,094,326	$62,830	$2,157,156	$2,125,741	$ 1,212,281	$ 587,785
20	385.8	11.6	397.4	391.6	$2,157,156	$64,715	$2,221,871	$2,189,513	$ 1,212,281	$ 565,812
									$ 23,639,479	$ 16,063,088

Table 35. Estimated Value of Evening Delay Avoided by Implementation of Congestion-Clearing Payments to Passengers at Half Moon Bay Bottleneck

Evening Delay			
	50%	3%	7%
Year		Delay cost in present value	Delay Cost in present value
1	$ 312,162	$ 303,070	$ 291,740
2	$ 643,054	$ 606,140	$ 561,668
3	$ 662,346	$ 606,140	$ 540,671
4	$ 682,216	$ 606,140	$ 520,459
5	$ 702,683	$ 606,140	$ 501,003
6	$ 723,763	$ 606,140	$ 482,274
7	$ 745,476	$ 606,140	$ 464,245
8	$ 767,840	$ 606,140	$ 446,890
9	$ 790,876	$ 606,140	$ 430,184
10	$ 814,602	$ 606,140	$ 414,102
11	$ 839,040	$ 606,140	$ 398,622
12	$ 864,211	$ 606,140	$ 383,720
13	$ 890,137	$ 606,140	$ 369,375
14	$ 916,842	$ 606,140	$ 355,567
15	$ 944,347	$ 606,140	$ 342,275
16	$ 972,677	$ 606,140	$ 329,479
17	$ 1,001,857	$ 606,140	$ 317,162
18	$ 1,031,913	$ 606,140	$ 305,306
19	$ 1,062,871	$ 606,140	$ 293,893
20	$ 1,094,757	$ 606,140	$ 282,906
		$ 11,819,730	$ 8,031,541

Table 36. Estimated Reductions in Fuel Use and Emissions from Reduced Delay at Half Moon Bay Bottleneck

Reduction in fuel and emissions														
	Year	Daily hours of vehicle delay	Daily hours of idling	Daily Litres of Gasoline	Daily Gallons of Gasoliine	Days per year	Gallons per Year	Fuel Cost Avoided	3%	7%	Tonnes of CO_2-e per year	Annual price of emissions	Emissions Avoided	3%
1	2021	111.65	109	196	51	200	10,200	$ 39,372	$ 38,225	$ 36,796	93	$ 50.00	$ 4,650	$ 4,515
2	2022	230	223.3	402	104	200	20,800	$ 80,288	$ 75,679	$ 70,127	190	$ 52	$ 9,873	$ 9,306
3	2023	236.9	228.7	412	107	200	21,400	$ 82,604	$ 75,594	$ 67,429	194	$ 53	$ 10,271	$ 9,399
4	2024	244	234.2	422	109	200	21,800	$ 84,148	$ 74,764	$ 64,196	199	$ 54	$ 10,730	$ 9,534
5	2025	251.3	239.8	432	112	200	22,400	$ 86,464	$ 74,585	$ 61,648	204	$ 55	$ 11,200	$ 9,661
6	2026	258.85	245.6	442	115	200	23,000	$ 88,780	$ 74,352	$ 59,158	209	$ 56	$ 11,679	$ 9,781
7	2027	266.65	251.5	453	117	200	23,400	$ 90,324	$ 73,442	$ 56,249	214	$ 57	$ 12,169	$ 9,894
8	2028	274.65	257.6	464	120	200	24,000	$ 92,640	$ 73,131	$ 53,917	219	$ 59	$ 12,882	$ 10,169
9	2029	282.9	263.7	475	123	200	24,600	$ 94,956	$ 72,776	$ 51,650	224	$ 59	$ 13,176	$ 10,099
10	2030	291.4	270.1	486	126	200	25,200	$ 97,272	$ 72,380	$ 49,448	229	$ 61	$ 13,920	$ 10,357
11	2031	300.15	276.5	498	129	200	25,800	$ 99,588	$ 71,944	$ 47,314	235	$ 62	$ 14,515	$ 10,486
12	2032	309.15	283.1	510	132	200	26,400	$ 101,904	$ 71,473	$ 45,247	241	$ 63	$ 15,122	$ 10,606
13	2033	318.4	289.8	522	135	200	27,000	$ 104,220	$ 70,969	$ 43,248	246	$ 64	$ 15,676	$ 10,675
14	2034	327.95	296.7	534	138	200	27,600	$ 106,536	$ 70,433	$ 41,316	252	$ 65	$ 16,306	$ 10,780
15	2035	337.8	303.8	547	142	200	28,400	$ 109,624	$ 70,363	$ 39,733	258	$ 66	$ 16,947	$ 10,878
16	2036	347.95	311	560	145	200	29,000	$ 111,940	$ 69,757	$ 37,918	264	$ 67	$ 17,600	$ 10,968
17	2037	358.4	318.3	573	148	200	29,600	$ 114,256	$ 69,127	$ 36,171	270	$ 68	$ 18,265	$ 11,050
18	2038	369.15	325.9	587	152	200	30,400	$ 117,344	$ 68,927	$ 34,718	277	$ 70	$ 19,281	$ 11,326
19	2039	380.2	333.5	600	155	200	31,000	$ 119,660	$ 68,240	$ 33,087	283	$ 72	$ 20,254	$ 11,551
20	2040	391.6	341.4	615	159	200	31,800	$ 122,748	$ 67,963	$ 31,720	290	$ 73	$ 21,039	$ 11,649
									$ 1,404,124	$ 961,090	4591			$202,684
				Year 1 with 50% added for evening				$ 59,058					$ 6,975	
				Year 2 with 50% added for evening				$ 120,432					$ 14,809	
				Totals with 50% added for evening					$ 2,106,186	$ 1,441,635				$304,026

Table 37. Estimated Value of Convenience of Traveling at Preferred Times Due to Congestion-Clearing at the Half Moon Bay Bottleneck

	Daily hours of inconvenienc		2,224				
		Value per hour	$25			3%	7%
	Commuters Going Early (end) (includes drivers)	% Commuters going early	Daily Convenienc e Value if none going early	Residual Convenienc e value in year dollars	Annual Convenience Value	Convenience Value in present value	Convenience Value in present value
Year 01	431	10%	$55,600	$50,041	$5,004,129	$ 4,858,378	$ 4,676,756
Year 02	572	13%	$55,600	$48,456	$9,849,771	$ 9,284,354	$ 8,603,172
Year 03	718	16%	$55,600	$46,918	$9,537,421	$ 8,728,092	$ 7,785,377
Year 04	868	18%	$55,600	$45,436	$9,235,334	$ 8,205,475	$ 7,045,592
Year 05	1023	21%	$55,600	$43,999	$8,943,474	$ 7,714,719	$ 6,376,573
Year 06	1184	23%	$55,600	$42,600	$8,659,950	$ 7,252,572	$ 5,770,490
Year 07	1349	26%	$55,600	$41,256	$8,385,639	$ 6,818,292	$ 5,222,154
Year 08	1520	28%	$55,600	$39,950	$8,120,570	$ 6,410,453	$ 4,726,246
Year 09	1697	30%	$55,600	$38,682	$7,863,136	$ 6,026,439	$ 4,277,025
Year 10	1879	33%	$55,600	$37,459	$7,614,101	$ 5,665,606	$ 3,870,623
Year 11	2067	35%	$55,600	$36,275	$7,373,438	$ 5,326,728	$ 3,503,067
Year 12	2262	37%	$55,600	$35,123	$7,139,851	$ 5,007,748	$ 3,170,179
Year 13	2463	39%	$55,600	$34,010	$6,913,382	$ 4,707,677	$ 2,868,808
Year 14	2670	41%	$55,600	$32,936	$6,694,598	$ 4,425,918	$ 2,596,280
Year 15	2884	43%	$55,600	$31,894	$6,482,913	$ 4,161,135	$ 2,349,706
Year 16	3106	44%	$55,600	$30,880	$6,277,360	$ 3,911,843	$ 2,126,359
Year 17	3334	46%	$55,600	$29,904	$6,078,412	$ 3,677,539	$ 1,924,270
Year 18	3570	48%	$55,600	$28,957	$5,886,085	$ 3,457,455	$ 1,741,480
Year 19	3814	50%	$55,600	$28,038	$5,699,525	$ 3,250,359	$ 1,575,966
Year 20	4065	51%	$55,600	$27,153	$5,519,115	$ 3,055,800	$ 1,426,244
						$ 111,946,582	$ 81,636,367

Table 38. Estimated Savings in Fuel and Maintenance Cost for VMT Avoided Due to Traveling as Passengers Instead of Drivers Through Half Moon Bay Bottleneck (Round Trip) of 43.52 Miles.

	Fuel and Maintenance Costs Avoided				
			$0.25	3%	7%
Year	Annual Passenger Trips	Vehicle Miles Avoided	Cost of fuel and maintenance avoided	Fuel & Maint Value in present value	Fuel & Maint Value in present value
1	250,400	10,897,408	$ 2,724,352	$ 2,645,002	$ 2,546,123
2	412,900	17,969,408	$ 4,492,352	$ 4,234,473	$ 3,923,794
3	443,300	19,292,416	$ 4,823,104	$ 4,413,823	$ 3,937,090
4	442,200	19,244,544	$ 4,811,136	$ 4,274,632	$ 3,670,393
5	442,000	19,235,840	$ 4,808,960	$ 4,148,251	$ 3,428,722
6	475,400	20,689,408	$ 5,172,352	$ 4,331,763	$ 3,446,557
7	477,400	20,776,448	$ 5,194,112	$ 4,223,288	$ 3,234,632
8	480,500	20,911,360	$ 5,227,840	$ 4,126,905	$ 3,042,650
9	517,300	22,512,896	$ 5,628,224	$ 4,313,565	$ 3,061,381
10	555,300	24,166,656	$ 6,041,664	$ 4,495,565	$ 3,071,276
11	562,000	24,458,240	$ 6,114,560	$ 4,417,288	$ 2,904,983
12	570,000	24,806,400	$ 6,201,600	$ 4,349,677	$ 2,753,585
13	611,900	26,629,888	$ 6,657,472	$ 4,533,414	$ 2,762,614
14	622,600	27,095,552	$ 6,773,888	$ 4,478,338	$ 2,627,031
15	634,600	27,617,792	$ 6,904,448	$ 4,431,702	$ 2,502,490
16	648,200	28,209,664	$ 7,052,416	$ 4,394,832	$ 2,388,897
17	663,300	28,866,816	$ 7,216,704	$ 4,366,225	$ 2,284,624
18	712,300	30,999,296	$ 7,749,824	$ 4,552,205	$ 2,292,893
19	730,500	31,791,360	$ 7,947,840	$ 4,532,542	$ 2,197,644
20	750,300	32,653,056	$ 8,163,264	$ 4,519,801	$ 2,109,543
				$ 85,783,291	$ 58,186,922

Table 39. Estimated Value of Emissions Avoided as a Result of Reduced VMT by Passengers Past Half Moon Bay Bottleneck

	Emissions Avoided					
		25	9.1096			3%
Year	Vehicle Miles Avoided	Fuel Use Avoided (gallons)	kg CO_2-e avoided	Price per tonne	Value of emissions avoided	Emissions Value in present value
1	10,897,408	435,896	3,970,841	$ 50.00	$ 198,542	$ 192,759
2	17,969,408	718,776	6,547,765	$ 51.96	$ 340,227	$ 320,697
3	19,292,416	771,697	7,029,848	$ 52.94	$ 372,168	$ 340,587
4	19,244,544	769,782	7,012,404	$ 53.92	$ 378,120	$ 335,955
5	19,235,840	769,434	7,009,232	$ 54.90	$ 384,821	$ 331,950
6	20,689,408	827,576	7,538,889	$ 55.88	$ 421,291	$ 352,824
7	20,776,448	831,058	7,570,605	$ 56.86	$ 430,485	$ 350,024
8	20,911,360	836,454	7,619,765	$ 58.82	$ 448,221	$ 353,830
9	22,512,896	900,516	8,203,339	$ 58.82	$ 482,549	$ 369,834
10	24,166,656	966,666	8,805,943	$ 60.78	$ 535,263	$ 398,286
11	24,458,240	978,330	8,912,191	$ 61.76	$ 550,459	$ 397,663
12	24,806,400	992,256	9,039,055	$ 62.75	$ 567,156	$ 397,792
13	26,629,888	1,065,196	9,703,505	$ 63.73	$ 618,361	$ 421,073
14	27,095,552	1,083,822	9,873,186	$ 64.71	$ 638,853	$ 422,357
15	27,617,792	1,104,712	10,063,482	$ 65.69	$ 661,033	$ 424,292
16	28,209,664	1,128,387	10,279,150	$ 66.67	$ 685,277	$ 427,042
17	28,866,816	1,154,673	10,518,606	$ 67.65	$ 711,553	$ 430,501
18	30,999,296	1,239,972	11,295,647	$ 69.61	$ 786,266	$ 461,848
19	31,791,360	1,271,654	11,584,263	$ 71.57	$ 829,070	$ 472,807
20	32,653,056	1,306,122	11,898,251	$ 72.55	$ 863,206	$ 477,936
	478,824,448		174,475,968			$ 7,680,057

Table 40. Estimated Value of Parking Costs Avoided at Destination End Due to Passenger Travel Though Half Moon Bay Bottleneck

	Parking costs avoided			
		$1.00	3%	7%
Year	Trips Avoided	Parking cost avoided	Parking costs in present value	Parking costs in present value
1	250,400	$ 250,400	$ 243,107	$ 234,019
2	412,900	$ 412,900	$ 389,198	$ 360,643
3	443,300	$ 443,300	$ 405,682	$ 361,865
4	442,200	$ 442,200	$ 392,889	$ 337,352
5	442,000	$ 442,000	$ 381,273	$ 315,140
6	475,400	$ 475,400	$ 398,140	$ 316,779
7	477,400	$ 477,400	$ 388,170	$ 297,301
8	480,500	$ 480,500	$ 379,311	$ 279,655
9	517,300	$ 517,300	$ 396,467	$ 281,377
10	555,300	$ 555,300	$ 413,195	$ 282,286
11	562,000	$ 562,000	$ 406,001	$ 267,002
12	570,000	$ 570,000	$ 399,787	$ 253,087
13	611,900	$ 611,900	$ 416,674	$ 253,917
14	622,600	$ 622,600	$ 411,612	$ 241,455
15	634,600	$ 634,600	$ 407,326	$ 230,008
16	648,200	$ 648,200	$ 403,937	$ 219,568
17	663,300	$ 663,300	$ 401,307	$ 209,984
18	712,300	$ 712,300	$ 418,401	$ 210,744
19	730,500	$ 730,500	$ 416,594	$ 201,989
20	750,300	$ 750,300	$ 415,423	$ 193,892
			$ 7,884,494	$ 5,348,063

Table 41. Estimated Reduction to Regional Congestion Costs of Passengers Through Half Moon Bay Bottleneck

	Congestion Costs beyond the corridor			
		$8	3%	7%
Year	Trips Avoided	Regional Congestion Avoided	Regional Congestion at present value	Regional Congestion at present value
1	250,400	$ 2,003,200	$ 1,944,854	$ 1,872,150
2	412,900	$ 3,303,200	$ 3,113,583	$ 2,885,143
3	443,300	$ 3,546,400	$ 3,245,458	$ 2,894,919
4	442,200	$ 3,537,600	$ 3,143,112	$ 2,698,818
5	442,000	$ 3,536,000	$ 3,050,185	$ 2,521,119
6	475,400	$ 3,803,200	$ 3,185,120	$ 2,534,233
7	477,400	$ 3,819,200	$ 3,105,359	$ 2,378,406
8	480,500	$ 3,844,000	$ 3,034,489	$ 2,237,243
9	517,300	$ 4,138,400	$ 3,171,739	$ 2,251,015
10	555,300	$ 4,442,400	$ 3,305,563	$ 2,258,291
11	562,000	$ 4,496,000	$ 3,248,006	$ 2,136,017
12	570,000	$ 4,560,000	$ 3,198,292	$ 2,024,695
13	611,900	$ 4,895,200	$ 3,333,393	$ 2,031,334
14	622,600	$ 4,980,800	$ 3,292,896	$ 1,931,640
15	634,600	$ 5,076,800	$ 3,258,605	$ 1,840,066
16	648,200	$ 5,185,600	$ 3,231,494	$ 1,756,542
17	663,300	$ 5,306,400	$ 3,210,459	$ 1,679,870
18	712,300	$ 5,698,400	$ 3,347,209	$ 1,685,951
19	730,500	$ 5,844,000	$ 3,332,752	$ 1,615,915
20	750,300	$ 6,002,400	$ 3,323,383	$ 1,551,134
			$ 63,075,951	$ 42,784,501

Table 42. Estimated Value of Reduction to Crash Risk Due to Reduced VMT by Passengers Through the Half Moon Bay Bottleneck

	Reduced Crash Risk							
		0.598	2.681	$ 10,399,968	$ 139,805		3%	7%
Year	VMT Avoided	Fatalities avoided	Non-Fatality Crashes Avoided	Value of fatalities avoided	Value of crashes avoided	Total Value of crashes and fatalities avoided	Crash and fatality avoided at present value	Crash and fatality avoided at present value
1	10,897,408	0.065	0.292	$ 675,998	$ 40,823	$ 716,821	$ 695,943	$ 669,926
2	17,969,408	0.107	0.482	$ 1,112,797	$ 67,386	$ 1,180,183	$ 1,112,436	$ 1,030,818
3	19,292,416	0.115	0.517	$ 1,195,996	$ 72,279	$ 1,268,275	$ 1,160,651	$ 1,035,290
4	19,244,544	0.115	0.516	$ 1,195,996	$ 72,139	$ 1,268,135	$ 1,126,722	$ 967,454
5	19,235,840	0.115	0.516	$ 1,195,996	$ 72,139	$ 1,268,135	$ 1,093,904	$ 904,163
6	20,689,408	0.124	0.555	$ 1,289,596	$ 77,592	$ 1,367,188	$ 1,144,998	$ 911,015
7	20,776,448	0.124	0.557	$ 1,289,596	$ 77,871	$ 1,367,467	$ 1,111,876	$ 851,590
8	20,911,360	0.125	0.561	$ 1,299,996	$ 78,431	$ 1,378,427	$ 1,088,143	$ 802,257
9	22,512,896	0.135	0.604	$ 1,403,996	$ 84,442	$ 1,488,438	$ 1,140,764	$ 809,612
10	24,166,656	0.145	0.648	$ 1,507,995	$ 90,594	$ 1,598,589	$ 1,189,500	$ 812,642
11	24,458,240	0.146	0.656	$ 1,518,395	$ 91,712	$ 1,610,107	$ 1,163,176	$ 764,950
12	24,806,400	0.148	0.665	$ 1,539,195	$ 92,970	$ 1,632,165	$ 1,144,768	$ 724,701
13	26,629,888	0.159	0.714	$ 1,653,595	$ 99,821	$ 1,753,416	$ 1,193,991	$ 727,605
14	27,095,552	0.162	0.726	$ 1,684,795	$ 101,498	$ 1,786,293	$ 1,180,950	$ 692,755
15	27,617,792	0.165	0.74	$ 1,715,995	$ 103,456	$ 1,819,451	$ 1,167,836	$ 659,453
16	28,209,664	0.169	0.756	$ 1,757,595	$ 105,693	$ 1,863,288	$ 1,161,139	$ 631,160
17	28,866,816	0.173	0.774	$ 1,799,194	$ 108,209	$ 1,907,403	$ 1,154,010	$ 603,835
18	30,999,296	0.185	0.831	$ 1,923,994	$ 116,178	$ 2,040,172	$ 1,198,386	$ 603,613
19	31,791,360	0.19	0.852	$ 1,975,994	$ 119,114	$ 2,095,108	$ 1,194,811	$ 579,315
20	32,653,056	0.195	0.875	$ 2,027,994	$ 122,329	$ 2,150,323	$ 1,190,582	$ 555,684
							$ 22,614,586	$ 15,337,838

Table 43. Local Economy Impact of Savings Due to Congestion-Clearing Payments to Passengers at the Half Moon Bay Bottleneck

		50%					Multiplier	1.25	3%	7%
Year	Delay Fuel Savings - morning	Delay fuel savings - evening	VMT vehicle running cost savings	Regional incentives	Administration	Marketing	Net Financial Benefits	Impact on local economy	Parking costs in present value	Parking costs in present value
1	$ 39,372	$ 19,686	$ 2,724,352	$ 2,003,200	$ (300,000)	$ (100,000)	$ 4,386,610	$ 5,483,263	$ 5,323,556	$ 5,124,544
2	$ 80,288	$ 40,144	$ 4,492,352	$ 3,303,200	$ (300,000)	$ (100,000)	$ 7,515,984	$ 9,394,980	$ 8,855,670	$ 8,205,939
3	$ 82,604	$ 41,302	$ 4,823,104	$ 3,546,400	$ (335,568)	$ (111,856)	$ 8,045,986	$ 10,057,483	$ 9,204,021	$ 8,209,902
4	$ 84,148	$ 42,074	$ 4,811,136	$ 3,537,600	$ (343,004)	$ (114,335)	$ 8,017,619	$ 10,022,024	$ 8,904,438	$ 7,645,754
5	$ 86,464	$ 43,232	$ 4,808,960	$ 3,536,000	$ (352,328)	$ (117,443)	$ 8,004,885	$ 10,006,106	$ 8,631,355	$ 7,134,215
6	$ 88,780	$ 44,390	$ 5,172,352	$ 3,803,200	$ (384,370)	$ (128,124)	$ 8,596,228	$ 10,745,285	$ 8,999,007	$ 7,160,037
7	$ 90,324	$ 45,162	$ 5,194,112	$ 3,819,200	$ (397,842)	$ (132,615)	$ 8,618,341	$ 10,772,926	$ 8,759,375	$ 6,708,837
8	$ 92,640	$ 46,320	$ 5,227,840	$ 3,844,000	$ (413,179)	$ (137,727)	$ 8,659,894	$ 10,824,868	$ 8,545,250	$ 6,300,171
9	$ 94,956	$ 47,478	$ 5,628,224	$ 4,138,400	$ (450,917)	$ (150,306)	$ 9,307,835	$ 11,634,794	$ 8,917,101	$ 6,328,557
10	$ 97,272	$ 48,636	$ 6,041,664	$ 4,442,400	$ (491,457)	$ (163,820)	$ 9,974,695	$ 12,468,369	$ 9,277,637	$ 6,338,286
11	$ 99,588	$ 49,794	$ 6,114,560	$ 4,496,000	$ (513,279)	$ (171,094)	$ 10,075,569	$ 12,594,461	$ 9,098,507	$ 5,983,538
12	$ 101,904	$ 50,952	$ 6,201,600	$ 4,560,000	$ (537,189)	$ (179,064)	$ 10,198,203	$ 12,747,754	$ 8,941,018	$ 5,660,155
13	$ 104,220	$ 52,110	$ 6,657,472	$ 4,895,200	$ (585,521)	$ (195,175)	$ 10,928,306	$ 13,660,383	$ 9,302,056	$ 5,668,573
14	$ 106,536	$ 53,268	$ 6,773,888	$ 4,980,800	$ (614,840)	$ (204,948)	$ 11,094,704	$ 13,868,380	$ 9,168,633	$ 5,378,397
15	$ 109,624	$ 54,812	$ 6,904,448	$ 5,076,800	$ (647,206)	$ (215,737)	$ 11,282,741	$ 14,103,426	$ 9,052,453	$ 5,111,731
16	$ 111,940	$ 55,970	$ 7,052,416	$ 5,185,600	$ (682,695)	$ (227,567)	$ 11,495,664	$ 14,369,580	$ 8,954,647	$ 4,867,474
17	$ 114,256	$ 57,128	$ 7,216,704	$ 5,306,400	$ (721,019)	$ (240,342)	$ 11,733,127	$ 14,666,409	$ 8,873,418	$ 4,643,009
18	$ 117,344	$ 58,672	$ 7,749,824	$ 5,698,400	$ (783,638)	$ (261,215)	$ 12,579,387	$ 15,724,234	$ 9,236,330	$ 4,652,233
19	$ 119,660	$ 59,830	$ 7,947,840	$ 5,844,000	$ (828,281)	$ (276,096)	$ 12,866,953	$ 16,083,691	$ 9,172,304	$ 4,447,275
20	$ 122,748	$ 61,374	$ 8,163,264	$ 6,002,400	$ (876,330)	$ (292,112)	$ 13,181,344	$ 16,476,680	$ 9,122,738	$ 4,257,887
									$ 176,339,514	$ 119,826,514

Table 44. Allocation of Benefit of New Employment of People who Start Commuting Through the Half Moon Bay Bottleneck

Starting new commuters	985			
First year adjustment factor	50%	going to work		
Annual value	$4,800	75%	3%	7%
Year	New commuters cummulative	Annual Value	Job access value in present value	Job access value in present value
1	492.5	$ 1,773,000	$ 1,721,359	$ 1,657,009
2	1121	$ 4,035,600	$ 3,803,940	$ 3,524,849
3	1262	$ 4,543,200	$ 4,157,672	$ 3,708,605
4	1408	$ 5,068,800	$ 4,503,563	$ 3,866,963
5	1558	$ 5,608,800	$ 4,838,200	$ 3,998,997
6	1713	$ 6,166,800	$ 5,164,598	$ 4,109,199
7	1874	$ 6,746,400	$ 5,485,441	$ 4,201,319
8	2039	$ 7,340,400	$ 5,794,580	$ 4,272,180
9	2210	$ 7,956,000	$ 6,097,612	$ 4,327,537
10	2387	$ 8,593,200	$ 6,394,148	$ 4,368,347
11	2569	$ 9,248,400	$ 6,681,241	$ 4,393,848
12	2757	$ 9,925,200	$ 6,961,336	$ 4,406,907
13	2952	$ 10,627,200	$ 7,236,606	$ 4,409,910
14	3153	$ 11,350,800	$ 7,504,216	$ 4,402,036
15	3360	$ 12,096,000	$ 7,763,962	$ 4,384,147
16	3574	$ 12,866,400	$ 8,017,915	$ 4,358,295
17	3796	$ 13,665,600	$ 8,267,913	$ 4,326,179
18	4024	$ 14,486,400	$ 8,509,233	$ 4,286,003
19	4260	$ 15,336,000	$ 8,745,907	$ 4,240,532
20	4504	$ 16,214,400	$ 8,977,520	$ 4,190,109
			$ 126,626,962	$ 81,432,971

ABBREVIATIONS AND ACRONYMS

AAPOR	American Association for Public Opinion Research
ACS	American Community Survey
App	A computer application, typically installed on a smart phone
BCA	Benefit Cost Analysis
BCR	Benefit-to-Cost Ratio
C/CAG	City and County Association of Governments
CA	California
Caltrans	The California Department of Transportation
CAPRI	Congestion and Parking Relief Incentive, a program at Stanford University
CBD	Central Business District
CCPTP	Congestion-Clearing Payments to Passengers
CO_2-e	Carbon Dioxide Equivalent, the conversion of the impacts of several different greenhouse gases into a common measure of carbon dioxide equivalence
Coastside	The case study catchment; an area of Northern California along the coast of San Mateo County from Montara to Pescadero
Comsis	A private consulting firm that coordinated the work for an analysis of TDM methods in the 1990s
DOT	Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FL	Florida
GRH	Guaranteed ride home: a program that enables people who take alternatives to driving alone to access a ride home, usually in a taxi that is paid for by the program, in an emergency or if their ride is cancelled
HMB	Half Moon Bay
HOV	High Occupancy Vehicle
Kg	Kilogram
MPG	Miles Per Gallon

MTI	Mineta Transportation Institute
NextDoor	A neighborhood private social network that operates on the internet and is used for communication between people in a geographic area
NPV	Net present value, based on discounting future cash flows to the present at a given discount rate and deduction the present value of cash outflows from the present value of cash inflows
OR	Oregon
PV	Present Value, the value in today's money of a stream of cash flows, positive or negative, in the future, discounted using a discount rate
RFID	Radio Frequency Identification
SJSU	San Jose State University
SMS	Short Message Service
SOV	Single Occupant Vehicle
SR	State Route, a naming convention for highways controlled by the state
StdDev	Standard deviation, a statistical measure of variability
SWITRS	Statewide Integrated Traffic Records System, a CA solution for recording traffic and related incidents
TDM	Transportation Demand Management
The Method	Method for estimating the benefits and costs of a potential congestion-clearing payments to passengers implementation
TMA	Transportation Management Association, generally a destination-based agency that seeks traffic reduction for a destination
Tonne	A metric ton (1,000 kg)
USDOT	The United States Department of Transportation
VA	Virginia
VKT	Vehicle Kilometers Traveled
VMT	Vehicle Miles Traveled
VTPI	Victoria Transportation Policy Institute

ENDNOTES

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PEER REVIEW

San José State University, of the California State University system, and the Mineta Transportation Institute (MTI) Board of Trustees have agreed upon a peer review process required for all research published by MTI. The purpose of the review process is to ensure that the results presented are based upon a professionally acceptable research protocol.