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Congestion-clearing payments to passengers

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Abstract

This paper reports on a project that considers whether the goals of (de)congestion pricing could be achieved in whole or in part by incentivizing mode-shift rather than using charging to force it: buying rather than selling decongestion.
The project developed a method for estimating the net present value of the costs and benefits of a permanent ITS-enabled program of paying people to travel as passengers rather than as drivers – to reduce existing congestion in a target corridor to a target maximum level of delay – taking into account the mix of the traffic and the potential impact of latent demand and induced trips. This is relevant for making better use of existing infrastructure (a "build nothing" alternative to expansion, but not a "do nothing" one), for decarbonizing transport, and in the run up to automated vehicles where the possibility exists that new infrastructure investments in the 1 – 20-year timeframe will become stranded assets under some future scenarios.
The project incorporated: a thorough review of the literature; focus groups; and a survey in a case study corridor in California to test the theory, develop the method, and determine the likely costs and benefits. The main insights include 1) the significance of an 'intra-peak demand shift' that would occur if congestion was removed; 2) the need for four major components in a congestion-clearing payments program: a) incentives to switch from driving to being a passenger, b) incentives to travel at less preferred times, c) park and ride/pool facilities near the bottleneck to ease the passenger switch, and d) some limitation on single-occupant vehicle travel in the peak-of-the-peak in order to reserve space for vehicles carrying passengers; and 3) the possible need for different land-use regulations in a successful "payments to passengers" environment where the amount of traffic might no longer be an obvious constraint for expanding the local economy. The case study benefit cost analysis delivers a benefit cost ratio of 4.5 to 1.

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Keywords: Reverse tolls; congestion pricing; decongestion pricing; traffic congestion; multimodal transportation; sustainable transportation; carpooling; ridesharing; mobility management; transportation demand management; incentives; mode shift; travel behaviour; user perspective; CO_2 emissions reduction; park-and-ride; park-and-pool;

1. Introduction

"*For the time being, the only relief for traffic-plagued commuters is a comfortable, air-conditioned vehicle with a well-equipped stereo system, a hands-free telephone, and a daily commute with someone they like.*" (Downs, 2004).

This paper focuses on recurring traffic congestion on major urban highway corridors. It explores the novel strategy of buying decongestion from passengers – perhaps commuting with someone they like. It describes how to reduce traffic by motivating drivers to ride as passengers and enlarging the number of passengers in each remaining vehicle. It assumes that people are price-sensitive in their mode-choice decisions such that at higher incentive levels more people will travel as passengers in higher occupancy vehicles. It extends the idea to paying enough money to enough people that the current traffic volumes that are excess to capacity, plus any latent demand and induced trips, could be removed on a permanent basis. It is important to note that the envisaged incentives would be paid to the passengers, not the drivers of the high occupancy vehicles. It would be up to the parties to decide how much the passenger should pay the driver, though the system might provide some guidance.

It is known that paying incentives can help to manage travel demand. Mode-shift incentives have been used to remove congestion in corridors for short periods of time. Experiments have tested paying incentives to drivers to drive outside the peak (Bliemer and van Amelsfort, 2010). Travel demand management uses incentives, usually over short periods, to reduce the total amount of traffic across a region or arriving at a specific destination. Some university campuses use incentives on an ongoing basis to manage the level of demand for parking (McCoy et al., 2016). However, the idea of buying decongestion in the manner described above to achieve a target level of congestion in a corridor on an ongoing basis has not been attempted or even extensively modelled.

In a real example of incentive payments for passenger travel, a consortium of local governments in concert with a travel management association in San Mateo County, California paid US$2 to each passenger and driver in carpools, twice per day, for carpools traveling within the confines of San Mateo County during defined morning and afternoon peak periods, during 2017/18. At a cost of $8 per vehicle-round-trip avoided, participation levels grew over eleven months until the project period ended. Commuters responded to the incentive, but the project summary documents do not state what proportion of the recipients of the funds were already carpooling, how many started carpooling in response to the incentive, and what impact the $893,000 spent had on regional traffic congestion (C/CAG, 2018).

This paper reports on a project funded by the USDOT through the Mineta Transportation Institute at San Jose State University. The project purpose was to put the idea of congestion-clearing-payments to passengers into a behavioural economics framework; to develop a method for preparing and evaluating a proposal for such a solution in a corridor; and to apply the method to a real situation that could be established as a pilot project (Mineta, 2018).

The project incorporated a literature review, focus groups, and development of a survey tool that was used in a case study corridor to inform expectations of the congestion-clearing price, the latent demand, and the likelihood that enough travelers on the corridor, mainly commuters, would respond. Accumulated data from the route was analysed, a benefit cost analysis (BCA) was carried out including 20-year net present value (NPV) calculations in a manner consistent with likely evaluation of other potential solutions, and a final report was written (see Figure 1).

The paper is organized as follows: Section 2 reports on the literature review; Section 3 discusses the concepts, outlines the draft method, and works through some calculations, Section 4 shares some results from the case study, and Section 5 draws conclusions and describes next steps.

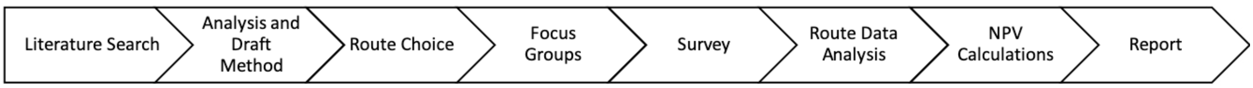

Figure 1: Research Schematic

2. Literature Review

Vickrey discussed the idea of using incentives to remove a traffic queue (Vickrey, 1967). He discarded the idea in favour of charging tolls to achieve the same end. Congestion tolls have been attempted in a very small number of locations and are generally politically challenging. In the early 2000's an experiment in the Netherlands called SpitsMijden (peak avoidance) paid drivers to change their time of departure to avoid the peak (Bliemer and van Amelsfort, 2010). Experiments carried out in Bangalore, India focused on using incentives to get bus passengers to change their time of departure (Merugu et al., 2009). Papers about the SpitsMijden and Bangalore experiments provide excellent overviews of the benefits of incentives rather than penalties as a method for bringing about mode-shift.

A key reason Vickrey gave for discarding the idea of paying incentives is "*the difficulty of ascertaining who would and would not have used the bottleneck facility during the critical period in the absence of both incentive and congestion*" (Vickrey, 1967). Various researchers have focused on payment for a *change* in the mode or time of travel, rather than for the mode or time decision itself (Vickrey, 1967, Bliemer and van Amelsfort, 2010, and Merugu et al., 2009). Therefore, the concept is characterized here as 'buying decongestion', rather than 'incentivising change.'

The reader might see that payment of an incentive is in effect a negative toll, and the opportunity cost of not taking up an incentive is the equivalent of a charge. Drivers who are 'tolled off' in a tolling scheme revert to public transport, carpooling, or other modes, times, or routes of travel, or do not travel, and so a tolling scheme reduces trips and congestion. Drivers who switch due to a passenger incentive potentially deliver the same result. The literature, however, contains concerns that some new travel will be induced by the payment of an incentive, and that behavioural economics suggests penalties are more powerful than rewards, both of which will need to be taken into account when estimating the cost and impact of a congestion-clearing-payments to passengers alternative.

"*A reward system <u>may</u> be less effective than a tolling system, but if tolling is politically infeasible a more relevant comparison is between a reward system and the absence of any control through financial mechanisms.*" (Rouwendal et al., 2010).

3. Discussion

To evaluate the practicality of paying incentives at congestion-clearing levels, two questions emerge: how many travellers would need to be incentivised, and how much would it cost? These questions need to be considered for both the current excess traffic and the future impact of latent demand and induced trips in the target corridor.

The benefit of answering these questions will be to give a realistic form to an alternative solution that could be considered when evaluating the options for resolving congestion in a corridor. Congestion-clearing payments to passengers could provide a 'build nothing – pay passengers' alternative that would have a very different set of impacts when compared with infrastructure expansion. Further, this form of road pricing reward could be more politically acceptable than imposing tolls.

An important question arises: where would the money come from to pay the incentives? While funding mechanisms exist to support infrastructure expansion, revenues to fund the costs of avoiding the need for expansion are not yet visible. However, the authors expect that if the 'congestion-clearing payments to passengers' method can be shown in theory and in pilot implementations to be an effective and economic way to manage traffic congestion, funding mechanisms would be created to support it.

Readers might also be wondering why the authors propose to pay incentives directly to passengers rather than the more traditional approach of subsidizing additional public transport. But note that underused public transport capacity often exists alongside significant levels of congestion. Private cars have much greater flexibility of origin, destination, and route than public transport and generally shorter trip times, especially if congestion can be managed away. It is the authors' opinion that paying incentives directly to passengers in buses, carpools, vanpools, or other modes will be more effective for managing demand and gaining additional co-benefits than providing subsidised public transport.

3.1. Method

A four-step method was drafted for the planning of a multi-year 'build nothing – pay passengers' alternative for a target corridor:

1. Determine the daily number of peak-period vehicles to be removed, each year, including assumptions of short-term latent demand and longer-run induced trips;
2. Calculate the cost each year of removing the target amount of traffic, considering the mix of traffic, driver behavioural segments, elasticity tables, existing HOV travel, and preferred incentive structures;
3. Calculate the present value of the annual costs to achieve the target future level of congestion via incentives, including the payments themselves, and administration and marketing;
4. Calculate the present value of the benefits (and any dis-benefits) that would flow from the solution over time, including economic, environmental, and equity benefits both within and beyond the transport system.

3.2. A Scenario – Extending Vickrey's Hypothetical Example

A corridor is envisaged with a bottleneck and a given flow of traffic, and it is assumed that:

- a mechanism is introduced that will make a payment to people who are traveling as passengers in the desired direction during the peak demand period;
- the amount of the incentive is sufficient to convince a congestion-clearing number of people to make their trip as a passenger rather than as a driver; and
- if demand changes, the amount of the incentive will be changed accordingly based on an assumption of elasticity.

Vickrey provided an example (Vickrey 1967):

"*To give a concrete illustration, suppose a bottleneck with a capacity of 4,000 cars per hour attracts, under current conditions, a volume of traffic of 4,400 cars per hour from 7:00 to 8:30, after which the traffic falls off to 2,800 cars per hour. Under these conditions the queue will build up linearly from nil at 7:00 to 600 cars at 8:30, and thereafter decline to zero again at 9:00. The maximum delay, for cars arriving at 8:30, will be 9 minutes, and the average delay 4.5 minutes; the number of cars delayed will be 8,000, or a total delay of 600 vehicle-hours.*"[†]

He goes on to say:

"*if it were possible to select, from among those who would be a part of the peak traffic if left to their own devices, those who have alternatives that they regard as not very much inferior to the use of the congested facility, and to offer them a bonus for shifting to these alternatives, it might be possible to eliminate the queuing by paying a bonus of, say, 25 cents per vehicle trip to 600 drivers - a total cost of $150*".

To reiterate: provision of an incentive sufficient to convince 600 drivers to switch to traveling as passengers would remove the queue. The current excess traffic is 600 vehicles.

Assuming such an offer was made, and assuming it takes three months to have full effect, after three months there would no longer be a queue, and the delay experienced by the 8,000 vehicles would have evaporated. From an economist's point of view, this reduced delay is a *social gain* and the money paid as incentive is defined as a transfer (Rouwendal et al., 2010).

3.3. Latent Demand in the Short-term

For anyone to be considering this particular bottleneck as an issue, it must be that the 9-minute maximum, and 4.5-minute average delay, is causing problems. It is likely that some drivers are avoiding this route, or traveling before or after the peak, or perhaps by different modes, or even not travelling, to avoid the delay. If the queue disappears, some of these people can be expected to revert to the route again. These people are latent demand, also referred to as suppressed traffic (Department for Transport, UK, 2017). Vickrey did not address this issue in his example. As these

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[†] Vickrey's example was actually an afternoon-peak queue. It is recast here as a morning queue because the largest driver of afternoon mode-choice is morning mode-choice.

people revert to the route, the queue will again begin to grow. However, according to policy, the incentive will be raised in order to again remove the queue. To estimate the cost of the proposal, it is important to predict latent demand.

It has been suggested (anecdotally) that suppressed or latent demand (for peak period travel) is as much as 100% especially in highly congested corridors: meaning that for every vehicle removed from traffic, another waits to take its place. While this might be the case for the first round of queue removal, it is not clear if it would be the case for the second round, or the third round. At some point latent demand would be exhausted.

It will take time for all latent demand to materialise. Assuming it has taken three months for the queue to disappear, it will then take some further months for the latent demand to respond, for the incentive to be adjusted, and for the number of passengers to again increase, and the cycle to be repeated until there is no further latent demand. It is likely that there will be periods of 'overshoot' and 'undershoot' as the balance is sought. Litman finds it reasonable to expect that latent demand fully materialises within 12 months (Litman 2018).

3.4. Induced Trips in the Longer-Run

In the second year, the route will be impacted by natural population and economic growth, plus induced trips. Vickrey does not explore the impact of these on his single point analysis, but the literature confirms that these are very real. In an environment where the severity of the queue might have put a damper on residential and commercial expansion, the sudden removal of the queue might induce economic activity. For example, if there is vacant land upstream of the queue that could be developed for residential purposes, developers might react quite quickly.

Without exception the literature on induced trips is focused on the impact of adding new capacity to an existing congested facility. The impact of reclaiming road space is not explored at all. The impacts might be similar, but given the policy setting of raising the incentive to prevent the queue re-forming, the rules of thumb do not work. For example, one rule of thumb is that "*within a year or two of road improvement, on average, nearly half of the capacity added is filled by new traffic. And five or more years downstream, upwards of three quarters or more of the extra capacity gets absorbed*" (Cervero, 2001). This, and elasticity based on lane miles per population will not be relevant.

The increase in use comes mainly from economic expansion, and such expansion may have been suppressed by the existence of the queue. Land-use patterns may have been managed by the growing traffic congestion, rather than through effective land-use regulation. In some countries, approval of a 'new use' for a property takes into account the impact the new use will have on traffic patterns and demand, and available capacity (Hutton, 2013, p.34).

In a corridor where incentives are being used to manage traffic levels, new land-use policy and regulations might be required. In this situation, an activity that adds a vehicle to peak-period traffic would cause an increase to the present value of the future incentives to be paid, at a rate that would grow over time. Instead of development contributions to cover the cost of expanding infrastructure, developers could be required to make traffic management contributions to offset the present value of the additional cost of incentives their developments cause.

The effectiveness of such regulations would have an impact on the rate at which the number of incentivised passengers would grow, in year two and beyond. In the future, rather than observing a rate at which new capacity gets used up, the important factor might be the rate at which travel demand grows, in an environment where regulation, rather than the amount of traffic, helps moderate economic growth.

3.5. Calculating the Incentives

Vickrey assumed that $1.50 per vehicle hour (in 1967) or 25 cents for a 10-minute time saving, would be sufficient to convince 600 people to change their trip. This includes some unstated assumptions: that 600 drivers <u>could</u> change; that 600 drivers <u>would</u> change; that there are enough empty seats; and if the solution involves carpooling, that enough other drivers would become carpool drivers.

The forces of latent demand and induced trips will expand the number of people for whom the incentive needs to be sufficient. The magnitude of the adjustment will depend on a long list of assumptions about the corridor in which the bottleneck exists, and the people who use it. For a real implementation, each of these factors must be estimated.

3.6. Reward Curves

In 1993 Comsis provided, and in 2016 VTPI updated, tables that can be used to estimate the impact on commuter traffic volumes of payments of different levels of rideshare or transit incentive, accompanied by various levels of parking charges at the destination end (Comsis, 1993, and VTPI, 2016). The Comsis work assumed all commuters would be offered the incentive, and all would be exposed to the parking charges. In Table 1 the incentive values have been deflated to 1967 dollars using the consumer price index, in order to be consistent with the Vickrey scenario:

Table 1. Response of commuter vehicle trips to daily rideshare/transit subsidies. Adapted from VTPI, 2016.

Worksite Setting	Rideshare/Transit Subsidy (1967 dollars) ($0.00 parking charge)				
	$0.00	$0.26	$0.51	$0.79	$1.02
Low density suburb, mode neutral	-	5.6	12.7	21.0	29.9
Activity centre, mode neutral	-	10.5	21.2	31.1	39.3
Regional CBD/Corridor, mode neutral	-	14.5	26.3	35.0	40.9

Values in the table indicate the percentage reduction in commute trips compared with no fees or subsidies.

3.7. Removing Excess Traffic and Latent Demand - Year 1

If Vickrey's bottleneck existed within a "mode neutral regional central business district (CBD)" (meaning that the amount of carpooling and transit use are about equal), the above table suggests that a $0.26 incentive would remove 14.5% of the commute trips. An incentive of $0.51 would remove 26.3% of commute trips. The initial 600 trips represent just 7.5% of all peak-period trips, so this table suggests that an incentive below $0.25 would be sufficient in the beginning, if all 8,000 peak period trips were commuter trips. Location-specific assumptions will be needed to decide if latent demand will push the first-year target above 7.5%.

A further question is: were all 8,000 trips in Vickrey's example commuter trips? Typically, some proportion of peak-period traffic will not be commuter traffic, but will be composed of through traffic, commercial vehicles traveling to work sites, freight deliveries, and a long list of other potential trip-purposes where it will be unrealistic for drivers to become passengers. To enable the use of the elasticity tables, the mix of traffic during peak must be established so that the true proportion of commuter trips to be reduced can be determined.

Supposing latent demand is 100% of current excess traffic, then the number of vehicles to be removed over the first year would be 1,200 instead of 600. Supposing 90% of the traffic, including the latent demand, is commuter traffic, then by the end of the first year, 15.5% of the commuter traffic would need to be incentivised. [(600 original excess plus 600 latent demand) / (8,000 original demand plus 600 latent demand) X 90% = 15.5%]. From the table above, by extrapolation, the incentive by the end of year 1 would need to be about $0.28 (in 1967 dollars).

The final test is whether the drivers would switch to being passengers. While segmentation would already influence the elasticity data in Table 1, it is important to do a sanity test, especially because Table 1 data is generalised across the country. Segmentation work by Winters et al. (2018), found that about four fifths of drivers are positively disposed towards taking actions that reduce the traffic, including carpooling. About 20% have very negative attitudes towards public transportation and do not enjoy carpooling. In Vickrey's example, as modified above, with 90% commuter traffic and latent demand equal to the current excess, total commuters in peak would be 7,740, and with 80% of this number positively disposed towards public transportation and carpooling, over 6,000 drivers (vs 1,200 needed) would be prepared to switch if the deal were good enough.

3.8. Dealing with Induced Trips and General Growth – Year 2 and Beyond

The number of induced trips will be specific to the corridor, the economy, and the quality of local regulations. Induced trips will be made up of a mix of trip purposes: freight, commerce, commuters, etc., and perhaps some people who just travel to get the incentive (though this is not considered highly likely given that both a driver and passenger would have to participate). Any induced trips will increase the proportion of commuters required to travel as passengers, and therefore move the required rate of incentive up the curve. For example, if the required percentage rises from 15.5% to 35%, the incentive to be paid to all passengers would rise from \$0.28 to \$0.79 (still in 1967 dollars), assuming that Table 1 holds true. Of course, such an increase might take many years. The rate of growth in the proportion of commuters to incentivise will be greater than the rate of growth of the traffic. A consistent set of assumptions should be used if evaluating competing options for resolving a given bottleneck.

4. The findings from the case study

4.1. Intra-peak demand shift

A representative survey asked users and non-users of the case study corridor (a California location with a long-standing bottleneck and congestion challenge) if and how they currently use the corridor, and if and how they would use the corridor if congestion went away, including changes to time and mode of use. 88% of current users would shift their time of use (71% to later, 17% to earlier) than currently. New users would add over 30% to the existing volume. This intra-peak demand shift would concentrate use into a later 'peak-of-the-peak' period than is currently observed, to such an extent that even if everyone willing traveled as a passenger, a new queue would form.

The survey asked if the respondent is the sort of person who would travel as a passenger, and if not then if they would for money, and if not that then if they would travel as a driver of passengers, and if not then if they would drive passengers for money, and from this all respondents were classified as a) drive only, alone, b) drive only, with passengers, or c) travel as passenger. In the case study corridor, the proportions were a) 27%, b) 23%, and c) 50%. Those who would travel as a passenger for money were asked how much they would want. Those who would drive passengers for money were asked how much they would want. A table in the format of Table 1 was able to be generated. The maximum of 50% of people prepared to travel as passengers would limit the impact the solution could have on the case study route to a maximum average occupancy of 2.0.

For the case study corridor, success would require all persons willing to travel as passengers to do so, causing the solution to incur the maximum cost for switching, in the order of \$15.00 per passenger per day. To facilitate this level of passenger travel, significant park-and-ride/pool capacity would be required near the bottleneck to make passenger travel as easy as possible. To counter the impact of intra-peak demand shift, an additional payment would be required to convince passengers to travel earlier or later than the peak-of-the-peak, to draw demand away and avoid the queue reforming. An unintended consequence would be that eventually the peak-of-the-peak would become dedicated to drive only, alone, travelers. Some form of limit would be required on drive only, alone, travelers during peak-of-the-peak to ensure passenger-carrying vehicles had priority, and to limit costs.

4.2. Benefit cost analysis

Benefits and costs were estimated for a 20-year period in line with the approach described above. In spite of the apparently high costs of passenger incentives, go-early-or-late incentives, and park-and-pool facilities, the total benefits were greater. These included reduced delay, reduced fuel use, reduced emissions, reduced vehicle wear and tear, reduced crash rate, reduced inconvenience, reduced parking costs, reduced congestion beyond the bottleneck, increased economic activity due to incentives in the hands of travelers, and increased earnings within the catchment. Some benefit categories were not quantified. The 20-year costs, discounted at 3%, came to \$141 million in 2019 dollars, while the benefits totaled \$640 million. The net present value of using this method to remove congestion at this bottleneck is therefore estimated to be half a billion dollars, with a benefit cost ratio of 4.5. The solution would avoid an estimated 181,000 tonnes of CO_2-e emissions over 20 years, included in the BCA at \$8 million.

4.3. Alternative solutions

There is no current plan to expand the facility that is the subject of the case study. The authors have performed a rough calculation using standard factors and estimate that the capital costs of expansion would fall in the range of \$70 million and \$370 million 2019 dollars. A full benefit cost analysis has not been performed for this alternative.

The alternative of congestion charging is generally not politically feasible and has not been evaluated.

5. Conclusion and Next Steps

Congestion-clearing payments to passengers is a strategy that has not been evaluated or tested before. If successful it could help to decarbonise transport while reducing demand for infrastructure expansion and avoiding stranded infrastructure assets in a low-price-robotaxi automated-vehicle-future envisioned by some (Grush-Niles, 2018).

The project successfully developed a method for evaluating congestion-clearing payments to passengers as a strategy, on a basis consistent with the type of benefit cost analysis that is performed for highway expansion projects (discounted 20-year cost and benefit flows). The method was used to estimate the physical impacts and benefits and costs of using the solution in a single case study corridor. The completed work has limitations but given the magnitude of the estimated benefits the authors think the next step should be a pilot project in the case study corridor, including additional surveying and firming up of estimates. The authors would also like to apply the method to find out if it would resolve congestion issues in additional locations around the world, and which local factors would make such a strategy more or less successful.

The full project report is currently with peer reviewers and is expected to be published in the first quarter of 2020.

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