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Greenhouse gas emissions from road construction: An assessment of alternative staging approaches

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A B S T R A C T

The greenhouse gas (GHG) emissions associated with road construction activities are analyzed. The main focus of this analysis is on the vehicle emissions associated with alternative project staging approaches, specifically a full closure of the road during construction, versus an intermittent road closure. The analysis includes the direct and upstream emissions associated with materials, construction equipment, mobilization of resources to the work site, and maintenance activity associated with the project over its lifetime. The analysis is based on one case study of a road project in New Jersey. The assumptions underlying the staging analysis are based on hypothetical approaches. Results provide an assessment of the main sources of project related emissions and the ability to minimize total project emissions by minimizing traffic disruption. In the analysis with a full closure of the road, traffic disruption accounts for 26% of total emissions, while with an intermittent road closure, traffic disruption accounts for only 2% of total emissions. The other main sources are from materials and life-cycle maintenance. The analysis demonstrates the feasibility of minimizing project related GHG emissions during road construction activities.

Introduction

Many transportation agencies are seeking ways to reduce emissions of greenhouse gases (GHG) from their own activities. The bulk of GHG emissions from the transportation sector, and in particular road transportation, is associated with decisions made by private vehicle users, and agencies have little ability to affect those decisions, short of major changes in policy. Where agencies can have a more immediate impact is in how roads are constructed and maintained over time. Previous research has suggested that the life-cycle GHG emissions associated with building roads can account for 10–20% of the emissions associated with the lifetime usage of the road by vehicles (Chester and Horvath, 2009; Noland and Hanson, 2015).

Previous research has shown that the bulk of the emissions associated with road construction and maintenance activities is often associated with the upstream emissions embodied in the materials used (Noland and Hanson, 2015). These materials primarily include asphalt, concrete, and steel. Transportation agencies typically have little discretion in the selection of materials, other than choosing concrete versus asphalt paving surfaces and with these there is some uncertainty as to which is more capable of reducing life-cycle GHG emissions (Noland and Hanson, 2011; Yu and Lu, 2012; Wang et al., 2012). The uncertainty is due mainly to how maintenance activities over the life of a road can maintain a smooth pavement surface, and

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how this affects rolling resistance and consequent emissions of vehicles using the road. With better information, this may be one way that agencies can reduce the life-cycle GHG emissions of their operations (Santero et al., 2011b).

One way to effectively reduce construction-related emissions now is to implement project staging approaches that minimize the disruption to existing traffic using a road. As most projects are reconstruction or rehabilitations of existing highways, many projects on heavily traveled roads can have substantial disruptive impacts. This can occur from just placing a work zone along a highway; according to the Highway Capacity Manual, this reduces capacity by about 10% (Transportation Research Board, 2010). Diverting traffic onto alternative roads can increase total vehicle-miles traveled and decrease the efficiency of those vehicles if the capacity of the diverted routes is substantially lower.

The objective of the research reported here is to evaluate the life-cycle GHG emissions associated with a pavement rehabilitation project and to evaluate the GHG emissions associated with alternative project staging approaches. A key question is what fraction of total emissions are accounted for due to traffic disruption? Previous work has suggested this could be a significant source of excess emissions (Santero et al., 2011a). But more importantly, how much variation is there using different staging approaches? These questions are evaluated using the recently completed Greenhouse Gas Assessment Spreadsheet for Transportation Capital Projects (or GASCAP) model[1] developed for the New Jersey Department of Transportation (Noland and Hanson, 2011, 2014).

Project analysis

Background on selected project

The project analyzed was a pavement rehabilitation project in Gloucester County, New Jersey. This was a 2.8 mile stretch of state route 47 (between Howard St. in Clayton to the vicinity of High Street in Glassboro). This is a principal arterial with one-lane in each direction in an outer suburban area in South Jersey. The location is shown in Fig. 1. The specific details of the project are based on NJDOT contract no. 11110 awarded in 2011.[2] The project includes milling and paving of the road surface. We include inputs for materials, equipment, and lifecycle maintenance, but focus our analysis on how traffic is disrupted during construction of the project. Life-cycle maintenance was modeled assuming an asphalt inlay, which is assumed to have a 20 year service life. The successful bid for the contract was $1.3 million.

This project provides a useful case study of how traffic disruption can increase GHG emissions. It is on a state road where there are few comparable alternative routes. By its nature the project will result in disruption to traffic. Two project staging scenarios are tested to examine the impact of staging alternatives on GHG emissions. These are a full road closure with a detour, and an intermittent full road closure using the same detour route.[3] Excess emissions are calculated using existing estimates of traffic flow compared to changes during construction.

Analysis of project staging options

The actual way this project was staged is not known and our analysis of two staging options is hypothetical. Fig. 1 shows a map of the closure and detour routes. The portion of route 47 to be closed is shown in black. The detour route is shown in gray. The procedure for estimating changes in traffic are based on the *Highway Capacity Manual* (HCM) (Transportation Research Board, 2010). This requires several items of information on each of the road segments and these are listed in Table 1.

The detour route is 4.32 miles long and includes the following four segments:

- W. Academy Street – Co. 610 from MP 2.21 to 1.96 (0.25 miles).
- Aura Road – Co. 610 from MP 1.96 to 0.57 (1.39 miles).
- Main Street/Buck Road – Co. 553 from MP 37.95 to 40.51 (2.56 miles).
- West Avenue – US 322 from MP 17.72 to 17.84 (0.12 miles).

All segments including the diverted portion of route 47 are arterial roads with a single lane in each direction and no median. All segments are 12 feet wide or wider, except for Main Street/Buck Road which has a lane width of 11 feet for much of its length. All segments of both routes have combined shoulder widths less than what is needed to avoid a congestion penalty based on HCM calculations (12 feet or more) except for 0.3 miles of Main Street/Buck Road on the detour route. Speed limits are quite variable on all but the shortest segments of both routes. The average speed limits are weighted by distance and rounded to the nearest whole number. Changes between the base route and the detour route are weighted by VMT, except for total length. The number of access points was assumed to be 14 per mile for all segments. This assumption was based on a visual inspection of the area using Google Maps. Our analysis does not take into consideration any traffic

[1] The model is available for download at www.gascap.org or http://vtc.rutgers.edu/gascap/.
[2] The bid sheet details are available at http://www.state.nj.us/transportation/business/procurement/ConstrServ/awards11.shtm.
[3] The GASCAP model offers a number of alternative project staging options, including simply setting up a work zone, multiple lane closings, and both full and intermittent lane closings.