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499 Pages

Part 1

Planning Department <planning@edcgov.us>

FW: Saratoga Retail Phase 2 - DR-R18-0001

1 message

Brooke E. Washburn <BWashburn@murphyaustin.com> Thu, Aug 16, 2018 at 2:19 PM
To: "planning@edcgov.us" <planning@edcgov.us>

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From: Brooke E. Washburn
Sent: Thursday, August 16, 2018 12:21 PM
To: 'charlene.tim@edcgov.us' <charlene.tim@edcgov.us>
Cc: 'Timothy White' <tjwhitejd@gmail.com>; John Davey <jdavey@daveygroup.net>; 'john.hidahl@edcgov.us' <john.hidahl@edcgov.us>; 'jvegna@edcgov.us' <jvegna@edcgov.us>; Hilary Krogh - Saratoga <hilaryd73@gmail.com>; 'Kim S - Camom' <CAmom2345@hotmail.com>; Rebecca - neighbor <rebecca.isbell@ymail.com>; 'Wes Washburn' <weswashburn@yahoo.com>
Subject: Saratoga Retail Phase 2 - DR-R18-0001

Dear Charlene,

Attached is public comment submitted by affected and concerned residents with regard to a proposed project (Saratoga Retail Phase 2 - DR-R18-0001). Due to the size of the documentation to be submitted, I will send all attachments under separate cover. Kindly include all comments and attachments in the public record for the project (Saratoga Retail Phase 2 - DR-R18-0001), and submit the same to the commission in advance of the **August 23, 2018**, hearing.

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Memo re public comment- FINAL.pdf
262K

To:	EL Dorado County Planning Commission; Board Of Supervisors
From:	Concerned Residents (Brooke & Wes Washburn; Kim Camom, Rebecca and Justin Eno, Hilary Krogh, Brandy Dollis, Karen Anda)
CC:	El Dorado County Planning Department
Date:	8/13/2018
Re:	DR-R18-0001/Saratoga Retail Phase 2- Request to Deny Application or in the Alternative Require an EIR

To effectively summarize the substantial and overwhelming evidence submitted in opposition to the application referenced above, residents who all reside in adjacent villages submit this public comment collectively for consideration in advance of the upcoming hearing before the El Dorado Planning Commission on **August 23, 2018.**

Request: In reliance upon the evidence and arguments detailed below, this memorandum respectfully requests that the design review revision, commonly referred to as Saratoga Retail – Phase 2 (DR-R 18-0001), be denied with prejudice, or in the alternative that the project be stayed until a full EIR is conducted.

Summary of Pertinent Facts:

On January 22, 2009, the El Dorado County Planning Department and Commission published findings and a staff report that were the basis for approval of a commercial development commonly referred to as "Saratoga Retail." In the findings, the County stated on multiple occasions that the unique shape of the lot being developed would not allow the owner to comply with various county ordinances.

> The Planning Commission should be aware that as a result of the Saratoga Way realignment project undertaken by El Dorado County, an odd shaped parcel was created. The applicant has adapted the project to this odd shape, but unique circulation issues exist with respect to the site's ability to handle large vehicles due to the narrow width of the parcel in certain locations. **As a result of the parcel's limitations, a number of administrative relief findings have been requested.** (See, January 22, 2009, Staff Report, P. 2.)

There were a number of administrative relief findings granted to the owner of the Saratoga Retail project. Said relief was granted as to the entire project, not a single phase, and was exclusively conditioned upon affirmative representations from the owner that the project would NEVER be a tourist serving Retail Center. These representations regarding the type of establishments that would occupy the Retail Center are crucial because, as stated by the Planning Department in 2009, the odd shape of the parcel would not allow for proper traffic and parking circulation.

Again, based on the assurances that the Retail Center would not be tourist serving, In 2009, the County waived requirements for parking, drop-off, and loading for a commercial development. The specific parking relief granted to the owner was not limited to Phase I of the development, and further does not extend to new phases, if the use is changed to a tourist serving facility.

> Thus eight (8) RV parking spaces would be required for the proposed restaurant uses. The project does not include recreational parking spaces. However, the project exceeds the County requirements and would be sufficient to serve the **proposed commercial use given that the project is not a regional retail center, nor is it a tourist serving facility, and it is unlikely that it would draw recreational vehicles to the site.** Administrative relief findings from the strict compliance with the provisions for commercial use have been made and are included in the Findings for Approval, Attachment 2. (See, January 22, 2009, Staff Report, P. 2.)

The owner decided to develop the approved design in phases, and built the first of three proposed retail facilities in 2009, a Walgreens. Then, in 2017, the owner submitted a Design Review Revision that sought to add two (2) drive-through facilities in lieu of building the previously approved retail facilities to house boutique shops and restaurants. The owner's blatant departure from the promises made to secure administrative relief in the first instance captured the attention of the community and resulted in a significant movement to oppose the revision.

The county and its residents adopted clear design ordinances and regulations that must be followed to mitigate future problems related to capacity, safety, traffic, etc. In 2009, the proposed commercial use for the odd parcel could not comply with the existing regulations, and therefore a compromise was achieved through administrative relief. This relief did not absolve the owner from ever complying with County regulations should the "use" change. In fact, quite the opposite was clearly the intent of the relief. The County conditioned the approval of the project, provided the use would **never** be tourist serving. Why? Logic follows, with a tourist serving facility, all of the potential problems with traffic, safety and parking the original laws were designed to negate become amplified, to an unacceptable level of significant negative impact on the residents of this county and local community.

The Planning Commission denied the proposed Saratoga Retail – Phase II design revision and a staff memo was issued on January 11, 2018. Then, in late spring, the owner submitted a second Design Review Revision that sought approval for two buildings, the first of which would include a drive-through restaurant.

Again, this submission from the owner is a departure from the original conditions of approval in 2009, namely it proposes a tourist serving facility in the form of a drive-

through restaurant. Accordingly, the application does not comply with the original 2009 approved project, and further as a whole the entire project does not comply with the regulations in effect in this county both in 2009 and present day.

Analysis:

1. **The entire Design Revision application should be denied with prejudice.**

Setting aside the legal arguments that the original permit was not properly revived[1], and that the submission by the owner less than 12 months after a denial (El Dorado County Ordinance Sections 130.54.080(A); 130.54.70) was improper, this design review revision application should be denied because a drive-through will never be a conforming use for the subject parcel.

a. Findings Issued by the Planning Department are Fatally Flawed and Should not Be Adopted by the Commission or BOA:

As detailed above, and expressed numerous times in the prior findings by the Commission and Planning Department, the parcel at issue is odd shaped and a project cannot be designed in a manner that ever complies with the specific traffic and parking regulations adopted by the County (Sections 17.18.030.B.6; 17.18.060.16 & 18; 17.18.080.C.) The owner currently is attempting to circumvent the regulations by presenting the project in phases, this is wholly improper and should be rejected. Administrative relief was given for the entire project, not a single phase of development, and this relief cannot be applied in piecemeal. For example, Walgreens does not have a single RV parking spot. However, under the code it should have 1 spot for every 10 parking spaces. Thus, if the project is built in phases, and now the proposed use will include a ***tourist*** serving facility, the parking for buildings 2 and 3 must include enough RV spaces for the entire project, including phase 1 and Walgreens. The current application does not meet this requirement.

Next, and most important, the County adopted in 2015, eight (8) regulations that must be complied with when building a drive-through. (See, Community Design Standards, Parking and Loading Standards, Section H.) These conditions for approval are not overly burdensome, or ambiguous. Instead, when drafting these regulations, the intent was clear, create a buffer between drive-throughs and residential communities, and further, limit the locations wherein such facilities can be located to minimize their impact on our community. Designs are required to adhere to these conditions as evidenced by the use

[1] Administrative arguments including the improper revival of an expired permit and design approval are not waived for purposes of this public comment. Residents contend that the originally approved project was for a term of 1 year, and under the county ordinances was not properly revived for purposes of a design revision application. Further, the second design revision application is untimely as it is not a significant departure from the 2017 application, and pursuant to the findings of the Planning Commission is barred for term of 12 months from resubmittal.

of "SHALL" and "PROHIBITED". The County in adopting these ordinances left no room whatsoever for interpretation or discretionary approval.

> H. Drive-Through Facilities: Sites containing these facilities **shall** be in compliance with the following circulation and traffic control standards:
>
> **2. Ingress and egress from a drive-through facility shall be prohibited from driveway(s) directly facing a residential zone.**
>
> 3. A drive-through facility, including stacking areas for vehicles awaiting service, shall be a minimum of 50 feet from the nearest property line of any residentially zoned lot.
>
> 6. Stacking areas **shall** not block access to any parking area or space required of a business . . .
>
> 8. When a drive-through facility requires a Conditional Use Permit or is within a development that is subject to a discretionary permit, the review authority may impose a greater setback than is required under Paragraph 3 above, when it is determined necessary to mitigate the impacts from noise, air pollution, lights, or other land use conflicts. The review authority may deny any application for a drive-through facility if it finds that the facility will add to the cumulative air-quality impacts for a specified pollutant and the County is found to be in non-attainment[2] status of either federal or state air quality standards for that pollutant. (Community Design Standards, Parking and Loading Standards, Section H.)

The finding by the Planning Department that the Saratoga Retail – Phase II second proposed revision meets with the Parking and Loading Standards is clearly erroneous and a misstatement of fact. (See, Findings dated August 23, 2018, p. 5, section 3.4.) It is presumed the Planning Department intentionally ignored the language in the provisions above, specifically item no. 2. It is not possible for the design revision to comply with item no. 2, which is mandatory for a drive-through. This non-compliance is sufficient, on its own to deny this project with prejudice, as no amount of amendment to the design will ever rectify this non-compliance. Further, there is no room to approve a project that does not meet these minimal standards as the intention by the county in adopting the same was to require mandatory compliance.

Once enacted, a county ordinance or regulation has the same force and effect within county limits as a statute passed by the legislature has throughout the state. *Evola v. Wendt Const. Co.* (1959) 170 Cal.App.2d 21. Where the county regulation/ordinance requires a ministerial act to be done by a municipal officer or employee, and the officer neglects or refuses to do that act, the officer/employee may be compelled to respond in

[2] El Dorado County is a non-attainment county.

damages to the extent of the injury arising from the officer/employees conduct. *Ellis v. City Counsel of Burlingame* (1963) 222 Cal.App.2d 490.

The above referenced standards were adopted by the Board of Supervisors, who have the power in this county to legislate and enact laws. *City of Sausalito v. County of Marin* (1970) 12 Cal.App.3d 550. It is the obligation of the Planning Department, and the Planning Commission to adhere to the laws enacted by the Board of Supervisors, including the regulations referenced above. Failure to properly review projects in accordance with said laws exposes the county to liability and the individual employees for intentional failures to obey the laws of this county.

In addition to the erroneous finding that the design revision complies with the County's laws (ordinances and regulations), the findings and mitigated negative declaration issued by the Planning Department states in error that the proposed project is not located near any SENSITIVE RECEPTORS. As the crow flies, a public children's park (one of the few splash parks in EDH), an elementary school, a little league baseball field, and an elderly day care center are all situated less than .4 miles from the proposed project. The County Planning Department's failure to identify and mitigate the environmental impact on these sensitive receptors is unacceptable. Children and Seniors are the most vulnerable classes of residents in our community and they deserve the upmost care, arguably beyond the minimum standards adopted by CEQA.

Accordingly, and in light of the failures of the Planning Department to properly apply the laws of this County and the State to the subject application[3], the Commission and BOS should **deny this application with prejudice** and any subsequent application that contains a tourist serving drive-through facility.

2. **In the Alternative, the Commission should require an EIR be performed for the revisions proposed.**

When a fair argument can be made that a project will have significant effect on the environment, and evidence of such impact exists in the lead agency's record, the agency's decision to adopt a mitigated negative declaration will be set aside. (*Gentry v. City of Murrieta* (1995) 36 CA4th 1359. Futher, a mitigated negative declaration will be set aside if there is substantial evidence in the record that the conditions attached to its adoption are insufficient to mitigate project impacts. *California Native Plant Soc'y v. County of El Dorado*, (2009) 170 CA4th 1026. The following substantial evidence demonstrates that in addition to significant impacst to the environment stemming from this project, the mitigation detailed by the County in the Findings are inadequate to address the impacts or reduce the impacts to an level of insignificance. (See, *Keep Our Mountains Quite v.*

[3] Residents further contend that the failure of the Planning Department to initially reject this application on the grounds that a drive-through use does not comply with the laws of this County is grounds to reject all of the findings issued by the Planning Department. It is not the job of the residents to review the findings for accuracy.

County of Santa Clara (2015) 236 CA4th 714 (negative declaration set aside on basis of fair argument about noise and traffic); *Rominger v. County of Colusa* (2014) 229 CA4th 690 (negative declaration's analysis of traffic impacts of subdivision of industrial land inadequate); *Mejia v. City of Los Angeles* (2005) 130 CA4th 322 (rejecting negative mitigated declaration based on evidence of possible impacts to traffic)).

A significant effect on the environment is substantial adverse change in the physical environment in the area affected by the project. The effect need not be momentous, important, or long lasting to be significant. The term "significant" covers a spectrum ranging from "not trivial" through "appreciable" to "important" and even "momentous." (See, *No Oil Inc. v. City of Los Angeles* (1974) 13 C3d 68, 83.) An agency's determination whether to classify a particular impact as significant involves the exercise of discretion. Further, it calls for careful judgment on the part of the public agency involved, based to the extent possible, on scientific and factual data. (14 Cal. Code Regs. §15064(b).) Distinguishing between substantial and insubstantial environmental effects requires that the agency make a policy decision based in part on the setting. (*WM Barr & Co. v. South Coast Air Quality Mgmt. Dist.* (2012) 207 CA4th 406, 433.)

Cumulative Impacts:

In any event, and pursuant to Pub. Res. Code §21083(b) and 14 Cal. Code Regs. §15065(a), an EIR must be prepared when, after an initial study, the following certain specified impacts result:

- The project has possible environmental impacts that are individually limited but cumulatively considerable. (Pub. Res. Code Pub. Res. Code §21083(b)(2);

A mandatory finding of significance is required when a project's potential impacts are cumulatively considerable. "Cumulatively considerable" is defined to mean that the increased effects of a project are considerable when viewed in connection with the effects of past, current, and probable future projects. Pub. Res. Code §21083(b)(2). Under the provisions of this mandatory finding, the environmental impacts of other projects are relevant to the extent that they provide a context for assessing the impacts of the project under review. A determination in an initial study that a project will result in impacts described in 14 Cal. Code Regs. §15065(a)(1) will ordinarily require an EIR. Adoption of a mitigated negative declaration is not appropriate unless the evidence in the record demonstrates that the mitigation measures **will reduce all impacts** to a level of insignificance. (See, *San Bernardino Valley Audubon Society c. Metropolitan Water Dist.* (1999) 71 CA4th 382.)

The evidence relied upon by the applicant for Saratoga Retail 2, including reports from the county regarding population growth are stale, and do not reflect the cumulative effect of the proposed project with other pending and approved El Dorado Hills projects, including but not limited to the Saratoga Estates, El Dorado Hills Apartments, and various

Serrano developments. Taken collectively, these proposed and approved projects will dramatically increase traffic in and around the Saratoga Retail lot. The addition of any tourist serving facility, let alone a drive-though is evidence enough, when taken cumulatively with the surrounding projects to trigger the obligation to complete a full environmental impact report.

Initial Study:

Due to the unique location of the proposed project (proximity to a highway on-ramp) an initial study evaluating any change to the originally approved plan is mandatory. Further, an initial study must consider all phases of development, implementation, and operation, including phases planned for future implementation. (14 Cal. Code Regs. §15063(a)(1).) The rule logically follows from the principles that the "whole of the action" that may result in physical change must be considered (14 Cal. Code Regs. §15378(a)) and that environmental analysis should not be deferred. (See, Pub. Res. Code §21003.1.) The application in this instance is attempting to circumvent a complete initial study of the complete environmental impacts of the entire development by submitting this revision application in phases. This is improper and does not relieve the County of its obligation to complete full and comprehensive environmental initial study.

Proposed Mitigation:

As detailed below, the mitigation proposed by the County does not comply with State and local law. Primarily, mitigating traffic using a fee program (TIM) that is not certain to address or relieve the specific impacts identified in the traffic reports is improper. *California Native Plant Soc'y v. County of El Dorado* (2009) 170 CA4th 1026. The mitigation proposed by the county for traffic is two-fold 1) adjust traffic lights based on future studies, and 2) payment into a fee based program (TIM) to expand Saratoga Way should in the future the traffic become worsened. These mitigation recommendations do not comply with CEQA.

Condition a negative declaration on another agency's (Traffic/Transportation) future review of environmental impacts, without evidence of the likelihood of effective mitigation by the other agency is insufficient to support a determination by the lead agency that potentially significant impacts will be mitigated. *Sundstrom v. County of Mendocino* (1988) 202 CA3d 296. A negative declaration requiring formulation of mitigation measures at a future time violates the rule that members of the public and other agencies must be given an opportunity to review mitigation measures before a negative declaration is approved. (Pub. Res. Code §21080(c)(2).) Lastly, if there is substantial evidence in the record that a fee-based mitigation program will not actually mitigate the project's impacts, an agency cannot rely on a project's contribution to the program to support a mitigated negative declaration. *California Native Plant Soc'y v. County of El Dorado* (2009) 170 CA4th 1026. According to the County Directors and Board of Supervisor, the current Saratoga Expansion project does not include widening the road

at the Saratoga Retail location. Thus, payment into the fee program will not specifically address the traffic created by the proposed design. Further, the TIM program does not have any concrete plans to address the traffic impacts to surrounding intersections (Arrowhead and Mammoth) and neighborhoods as described in more detail below.

For these reasons, the County's mitigation findings are wholly inadequate and do not comply with CEQA.

Public Comments Regarding Significant Impact:

The public is entitled to review and comment on a proposed mitigated negative declaration. (14 Cal. Code Regs. §§ 15072-15073.) The lead agency must consider such comments when deciding whether to approve the negative mitigated declaration (14 Cal. Code Regs. §15074(b).)

Relevant personal observations of area residents on nontechnical subjects may qualify as substantial evidence for a fair argument that a particular project will significantly impact the environment. So may expert opinion if supported by facts, even if not based on specific observations as to the site under review. (See, *Pocket Protectors v. City of Sacramento* (2004) 124 Cal.App.4th 903.)

To constitute substantial evidence, statements by the public must be supported by adequate factual foundation. An adequate foundation may be established by relevant personal observations of the public. For example, neighbors' testimony about noise impacts based on past noise events constituted substantial evidence. *Keep our Mountains Quiet v. County of Santa Clara* (2015) 236 CA4th 714. ***Further, an owner of adjacent property, may, based on personal observations, testify to existing traffic conditions.*** *Citizens Ass'n for Sensible Dev. v. County of Inyo* (1985) 172 CA3d 151.

The residents who assisted in the preparation of this commentary collectively submit the following substantial evidence of significant impact for the County's record and consideration. All of which, either on its own, or collectively mandates that this project be stayed while a formal EIR is performed.

A. **Aesthetics: Scenic, Visual, Light and Glare Impact. The project will have a significant impact on the aesthetics of the surrounding community. Attached as Exhibit A to this commentary are copies of all supportive documentation relied upon in making this determination.**

    a. Summary of Substantial Evidence: Research supports that convenience stores and fast food restaurants located within close- proximity to a major thoroughfare are at a much higher risk of criminal activity than others. To this point, it was only a year ago that the Walgreens in the lot adjacent to the proposed site, had a truck drive through the front doors,

wrap a chain around the ATM, and attempted to drag the machine out the door.
"Corporations very often target specific demographics that equal high traffic and potential profit, while failing to properly prepare for the increased crime that invariably accompanies such site selections."
(J. R. Robert Security, You Want Fries with that Knuckle Sandwich? http://www.jrrobertssecurity.com/fast-food-crime-prevention-2/)

Research shows that fast food restaurants devalue nearby properties. First impressions last, and as you enter El Dorado County, the quality in La Borgata and Town Center, should be echoed within the Saratoga Retail area as well.
"We find that neighborhood context, especially access to fruit and vegetable outlets, is capitalized into, or associated with, higher housing values. Fast food and convenience store access are associated with lower housing values."

"All neighborhood incomes types place negative value on fast food access and convenience store access." (The price of access: capitalization of neighborhood contextual factors, Henry Shelton Brown, III and Lisa M Yarnell, Aug. 8, 2013)

A study done in the UK showed that premium restaurant brands had a positive effect on house price values, while "value" brands such as fast food, had an adverse effect on house prices. The statistics point to a decreased property value in homes located within walking distance of up to 24%.

"These places tend to cheapen a neighborhood, drive out other businesses and lower residential property values. Fast-food chains have the market power to establish themselves in a neighborhood thus depriving residential shoppers of the much-needed small retailers offering local services.

For these reasons, the industry's arguments that its restaurants raise taxes and create employment are quite simply false. They drive out local businesses, have no net effect on employment and actually lower property values. Further, they cause a flight of capital from the city. Large franchises send a large amount of profit out of the city back to corporate headquarters. Local shopkeepers, to the contrary, spend and reinvest their money right here at home." (Fast Food? In Our Neighborhood? June 23, 1985, The Washington Post)

"[T]here are some areas in which aesthetics and economics coalesce, areas in which a discordant sight is as hard an economic fact as an annoying odor or sound. We refer not to some sensitive or exquisite preference but to concepts of congruity held so widely that they are inseparable from the enjoyment and hence the value of property.4 1"

"The first major state court decision after Berman was the Wisconsin case of State ex rel. Saveland Park Holding Corp. v. Wieland"' which was based upon both aesthetics and the protection of property values.

The ordinance required that in order for a building permit to be issued, the city's zoning board had to find that the exterior architectural appeal and functional plan of the proposed building would not cause a substantial diminution of property values within the neighborhood.' 8 The court felt that the preservation of property values was a legitimate ground for the exercise of the police power. The judgment was based on the conviction that anything that destroys property values ultimately affects the prosperity and general welfare of the community," (Aesthetic Zoning: Property Values and the Judicial Decision Process; Sheldon Elliott Steinbacht, Missouri Law Review, Volume 35 Issue 2, Spring 1970)

B. **Air Quality: The project will have a significant impact on the air quality of the surrounding community. Attached as Exhibit B to this commentary are copies of all supportive documentation relied upon in making this determination.**

a. Summary of Substantial Evidence: Mattingly et al, 2008, *A Model for Estimating NO_X Emission Reductions after Closing Drive-Thrus*

This study demonstrates that closing a drive-through restaurant reduces local atmospheric NO_X (oxides of nitrogen) concentrations by 61-67% due to the elimination of idling automobiles. Conversely, we can infer that introducing a new drive-through restaurant will increase local NO_X concentrations to 250-300% of baseline levels.

Brand, 2016, *Beyond 'Dieselgate': Implications of unaccounted and future air pollutant emissions and energy use for cars in the United Kingdom*

Real-world vehicular NO_X emissions may be as much as 40 times higher than those claimed by vehicle manufactures and subsequently incorporated into environmental studies. Following this revelation, public policy must reconsider relevant regulations to account for unreported pollutants. Prior regulations crafted using false information may endanger public health if uncritically observed going forward.

Jerret at al, 2014, *Traffic-related air pollution and obesity formation in children: a longitudinal, multilevel analysis*

Air pollution has been correlated with the development of obesity in children. Traffic-generated atmospheric pollutants, such as NO_X, may cause inflammation which invokes further metabolic processes leading to diabetes and BMI increase. Proximity to freeways increases NO_X exposure, creating an elevated baseline of contact upon which additional sources (e.g., drive-throughs) must be added.

Kondo et al, 2014, *Place-Based Stressors Associated with Industry and Air Pollution*

Residing in proximity to a source of atmospheric pollution incurs not only physical effects from the respiration of fumes, but also psychological and social effects from the stigma of being associated with a blighted area and defensive apathy as a coping mechanism against the indifference of local government inadequately handling the situation.

Nykiforuk et al, 2018, *Adoption and diffusion of zoning bylaws banning fast food drive-through services across Canadian municipalities*

Fast food drive-through service bans may play a role in promoting healthier food environments. Reasons cited for banning fast food drive-throughs in various North American municipalities include addressing air pollution, idling, and environmental concerns as well as traffic, community safety and aesthetics, and may others.

Hill et al, 2016, *An Evaluation of the Effects of Drive-Through Configurations on Air Quality at Fast Food Restaurants*

Different fast food drive-through configurations (number of lanes, number of stops, etc.) result in different automotive emissions profiles. Aggregate vehicle idle time is a major source of pollution.

Kamieniecki et al, 1991, *Intergovernmental Relations and Clean-Air Policy in Southern California*

Automotive emissions within a valley geography result in concentrated air pollution, which affect negatively property, public health, and the environment in the amount of several billion dollars per year.

b. Critique of Proposed Mitigation: In addition to being a precursor compound to smog, NO_X also contributes to ozone (O_3) formation, per the AQMD website

(https://www.edcgov.us/Government/AirQualityManagement/Pages/air_quality_plans.aspx):

Ozone (O3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air. Generally ozone is created by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight.

Furthermore, according to the same AQMD website:

The Sacramento Region is currently designated nonattainment for the following criteria pollutants: ozone and particulate matter.

The logical conclusion here is that introducing a drive-through restaurant will increase atmospheric NO_X concentrations, thereby increasing ozone concentrations, which in turn drive this Region further from Ozone attainment status as established by the National Ambient Air Quality Standards (NAAQS). No mitigation has been proposed to address this.

The project proposal offers no mitigation. The research recommends a detailed study (e.g., an EIR) to accurately assess vehicle queueing patterns and wait times to estimate overall emissions from the indirect source.

c. Sensitive Receptors: Children and seniors all within .4 miles of the proposed project and idling cars with pollutants and emissions. The same AQMD website catalogs ozone's adverse health effects:

Ozone is a strong irritant that adversely affects human health...

We disagree that there would be no impact to sensitive receptors because "there are no nearby sensitive receptors." At a minimum, the proposed introduction of an ozone-generating business in close proximity to known Sensitive Receptors (Senior residents of Versante, children waiting at schoolbus stops on Kings Canyon Drive and otherwise living in the neighborhood) warrants a full EIR to assess potential impact. The County of El Dorado Senior Day Care for the elderly with "dementia and other chronic health issues" and the Senior Center is less than a half a mile away.

C. **Greenhouse Gas Emissions. The project will have a significant impact with regard to greenhouse gas emissions into the surrounding community. Attached as Exhibit C to this commentary are copies of all supportive documentation relied upon in making this determination.**

a. Summary of Substantial Evidence: Chick-Fila's website touts a drive-thru customer base of 90 cars, per hour, and operating from 6:30 am to 10pm (15.5 hours, 6 days a week/ 93 hours per week/4,836 per year)

"Business Insider" also published a comprehensive study demonstrating that the average "wait-time" per customer is 4 min 16 sec.

The City of Fort Collins, in cooperation with the EPA, determined that the average car- running at idle for 1 minute, produces 3.82 grams of carbon.

100 cars per hour X 15.5 hours per day (hours of operation) X 256 seconds (avg wait time) X 3.82 grams Carbon per minute, X 6 days per week X 52 weeks = 15,340 pounds of carbon, per year.

D. **Land Use & Planning: The project will have a significant impact on the land use and planning for this county, the project is not compliant with county codes and regulations. Attached as Exhibit E to this commentary are copies of all supportive documentation relied upon in making this determination.**

a. Summary of Substantial Evidence: For the reasons identified in the sections above regarding the design's failure to comply with County Design Standards, namely section 2, failure to comply with the general plan, and other county ordinances, this project triggers a full environmental report. Evidence that a project is inconsistent with land use standards adopted to mitigate environmental impacts can support a fair argument that a project might have significant adverse effects on the environment. *Pocket Protectors v. City of Sacramento* (2004) 124 CA4th 903.

E. **Noise: The project will have a significant impact in that it will generate and exceed acceptable levels of noise disrupting the surrounding community. Attached as Exhibit F to this commentary are copies of all supportive documentation relied upon in making this determination.**

a. Summary of Substantial Evidence: It makes no sense that the Mitigated Negative Declaration/Initial Study for DR-R18-0001 Saratoga Retail Phase 2 is currently being presented with either "No Impact" or "Less Than Significant Impact" checked in the Aesthetics and Noise areas. How is this even possible given that potentially significant impacts were identified in Aesthetics and Noise in a Mitigated Negative Declaration in 2009? In 2009, a Mitigated Negative Declaration was prepared for the approved DR 08-0003/The Shops due to the "Potentially Significant Impact" of Aesthetics, Noise, Air Quality and Transportation/Circulation.

The Saratoga Retail Phase 2 proposal will result in more traffic noise, lighting/advertising signage and non-traffic noise (e.g., drive-thru window,

more HVHC units, additional compressors for the freezers/refrigeration systems, swamp coolers for the grill hoods, outside patio noise/music, car alarms, etc.) than were identified in 2009. The outside grease disposal containers and additional trash containers, etc. are not even addressed in terms of noise and aesthetics.

The drive-through order window proposed for building 3 would likely be in operation during nighttime hours (past 10 p.m.) according to the Initial Study (page 43). For a drive-thru which is "pushed right next to a residential neighborhood" it is a "Never-ending nuisance of late-night hours." There is "extended documentation of the noise, trash, and passed out people..." "Because late-night drive-thrus don't offer bathrooms, many people simply urinate in the alley... It is more like a wild after-party with cars idling, full of occupants yelling and radios blaring and horns honking" (MINNPOST, 8/28/15). Ironically, the proposed conditions also state "Walgreens includes a 24-hour drivethrough pharmacy" when it currently is not open past 10:00 p.m.

DR08-0003/ Saratoga retail Findings for Denial (January 8, 2018) states: "Of note, the Planning Commission finds that additional information and analysis is required to address potentially significant impacts to the following areas.... b. Noise: The record does not contain sufficient information or analysis to assess potential noise impacts associated with the Project. Although a noise analysis was performed, evidence presented at the hearing raised questions concerning the need to assess potential impacts to adjacent residents in two-story homes above the sound wall."

The project continues to rely on the August 31, 2017 Noise Analysis identified as "The Habit Burger Restaurant Project Noise Assessment." It states the "HELIX Environmental Planning, Inc. (HELIX) has performed a noise assessment for the operational impacts of the proposed The Habit Burger Restaurant Project (project)." Specifically, the "Project" is being defined as "The Habit Burger" and not DR08-0003/Saratoga Retail, which should include a noise study that includes all four buildings.

Because of the Highway 50 Project, which realigned Saratoga Way, certain mitigation measures were implemented. These mitigation measures included a sound wall, dual paned windows in only the second story of a handful of the impacted residences. At no time did the noise study measure actual noise levels after the rerouting of Saratoga Way or test the effectiveness of the mitigation measures. Most residences did not receive dual pane windows including townhouse residents who are at a higher elevation than the first row of six two story townhouses. Even the single-

story homes at a higher elevation have a clear, unobstructed view of Saratoga Way.

The neighboring Crescent Ridge homes by Finders Way are not benefitting from any noise reduction measures being implemented on the new Saratoga Estates homes. The inability to mitigate noise with a sound wall for homes at a higher elevation is also discussed in the Saratoga Estates Project Draft EIR. "Thus, it is possible that a 29 foot sound wall could potentially achieve the reduction necessary. However, this level of reduction would be considered 'very difficult' by FHWA standards. The Draft EIR states that "This impact would be significant and unavoidable."

There were assurances from both the developer and staff at the June 26, 2018 Saratoga Retail Neighborhood Meeting included that the 2009 Findings would remain intact. Limiting truck deliveries between the hours of 6 a.m. and 10 a.m. only was explicitly noted as a continued requirement. However, the Conditions of Approval deletes the requirement to limit strike-through, leaving neighbors with the possibility of being awakened by truck deliveries all night. Therefore, the nighttime noise from truck deliveries was not addressed.

The staff purpose of the condition was due to mitigate conflicting pedestrian traffic and trucks. However, its origins also come from the concern about noise. At the 2009 Planning Commission Hearing, Lou Rain, District 1 took the lead to ensure that truck deliveries for all buildings should be restricted so that people would not be awakened during the night. The 2009 Planning Commission agreed to require Building 1 (Walgreens) to also have restrictions on truck deliveries.

DR08-0003/ Saratoga retail Findings for Denial (January 8, 2018) states: "Of note, the Planning Commission finds that additional information and analysis is required to address potentially significant impacts to the following areas:" ....."The record also does not contain sufficient information or analysis of potential impacts generated by the Project's plan for product delivery, inclusive of the cumulative effect of the Project's anticipated deliveries with the existing Walgreen's product deliveries."

The Traffic Infusion on Residential Environment (TIRE) index for Mammouth Way, Arrowhead Drive and Finders Way was not identified, and therefore, there were no results to trigger a study of the impacts (e.g., noise, safety, harmful effects on human beings) within the neighborhood. A previous study (Dowling Associates, 2007) forecasted a TIRE Index of 2.9 for Arrowhead (860 cars daily) and a 3.0 for Finders (940 cars) in 2030. "The TIRE Index of 3.0 is normally used to determine that point at which a

residential street changes character and operates as a traffic facility." "Yet, any traffic change of 0.1 or more would be noticeable to street residents. Streets with TIRE levels above the mid-range index of three are traffic - dominated while those with indexes below three are better suited for residential activities." Dowling and Associates further stated that the analysis "Does not include traffic due to anticipated Mixed Use Center/Office Building Development in reference to reported neighborhood cut-through/diverted traffic volumes."

F. **Transportation/Traffic: The project will have a significant impact on the traffic for the surrounding community. Attached as Exhibit H to this commentary are copies of all supportive documentation relied upon in making this determination.**

a. Summary of Substantial Evidence: What follows below is traffic study information regarding three projects in EL Dorado Hills that will affect the traffic impact at several intersections. A very important, yet not studied, aspect is all of the traffic that will be generated when Saratoga Way is connected to Iron Point Road in Folsom. This connection will serve as a conduit for vehicles to get from El Dorado Hills to the many Broadstone Shopping Centers in Folsom in order to avoid the very heavily trafficked intersection of Scott Road / East Bidwell and Iron Point Road. Saratoga is poised to become heavily trafficked by local residents and NONE of the environmental studies addresses this traffic impact to El Dorado Hills Blvd. and Saratoga Way.

In light of the fact that there is NO information regarding the traffic effects of connecting Saratoga to Iron Point road, attached is Attachment A - "Traffic Study Analysis of Data 2018" conducted by Kim Shultz. The analysis uses the traffic data from the traffic studies submitted by the developers for the Saratoga Estates (Attachment B), the Town Center Apartments (Attachment C, Attachment D) and the new updated Saratoga Retail DR-R 18-0001 (Attachment E) and inputs the data into one Microsoft Excel spreadsheet. The purpose of this exercise is to show the varying outcomes of each projects traffic impact data in one document for comparison purposes. Ms. Shultz listed each projects study tables and subsequent results. Tables can be found in Attachment documents.

An important note is that the traffic studies for the Saratoga Estates and the Town Center Apartments that include affected intersections (namely Saratoga Way and El Dorado Hills Blvd and Latrobe Road / Town Center / Post Street) were conducted prior to the change in the updated DR-R 18-0001 with the addition of a fast food drive thru (Chik Fil A) and likely included the data from the previous DR-08-0003 which did not include a

fast food drive thru. Attachment F – "TC APTS Transportation Long Term Projects" lists the projects in their traffic study and a fast food drive thru Chik Fil A on Saratoga Way is not one of them.

Even without the consideration of the updated DR-R 18-0001 the Cumulative traffic impacts with those two residential building projects (Saratoga Estates and the Town Center Apartments) projects an unacceptable LOS F at these two intersections.

According the El Dorado County General Plan Policy TC-Xd (Attachment G), "The volume to capacity ratio of the roadway segments listed in Table TC-2 shall not exceed the ratio specified in that table." Interpreting this to mean: Level of Service (LOS) F is unacceptable.

In addition, because the traffic studies for the two projects (Saratoga Estates and the Town Center Apartments) were conducted before the updated DR-R 18-0001 with the addition of a fast food drive thru (Chik Fil A), the projected Level of Service for the freeway on and off-ramps may also be affected and according to the California Department of Transportation's "Guide for the Preparation of Traffic Impact Studies (Caltrans 2002)," it states, among other considerations, that, "In addition, a project impact is said to occur when the addition of project trips causes a queue on the off-ramp approach to a ramp terminal intersection to extend beyond it's storage area and onto the freeway mainline." Because Chik Fil A strives to deliver in the neighborhood of 100+ cars per hour during peak hours (Attachment I), combined with the LOS F data of the other two projects, the off-ramp (and on-ramps) may be affected, an EIR with an independent traffic consulting firm (a second opinion if you will) should be conducted.

In the DR-R 18-0001 Saratoga Retail, evidence is provided of Trip Generation data for three other Sacramento Area Chik Fil A's. This data was gathered only on one day in April, April 17, 2018. Making projections of traffic impacts from only one day's worth of data is misleading and misrepresentative of the true traffic impact that a popular fast food chain garners. Also, these Chik Fil A restaurants are not adjacent to a freeway whose very nature is to draw "eyeballs and hungry bellies" to it's tourist serving location. The other three locations do not share the kind of visibility from the freeway that the Saratoga location engenders. According to the County of El Dorado General Plan (Attachment G) "the addition of 10 or more trips during the am peak hour or the pm peak hour" and / or the "addition of 100 or more daily trips" defines these situations as "worsening", in the DR-R 18-0001 (Attachment E) the project proposes 2700 new daily trips! This scenario appears to be much worse.

Because of the impacts of the two aforementioned development projects, not to mention other area projects that have not been considered here, as well as the non-studied connection of Saratoga Way to Iron Point Road in Folsom, the combined traffic impact studies are resulting in conflicting data points that appear to not give an adequate accounting of the REAL traffic impact. Only a full environmental impact report that considers all the projects and their potential impact can help adequately address the transportation effects of a fast food drive thru, Chik Fil A, at the Saratoga / EDH Blvd. intersection as well as the residential roads Mammoth, Arrowhead and others.

Furthermore, each of these traffic studies was conducted by the same company, Kimley Horn, which their own data shows calculations between different projects is varying (Attachment A). Because of the critical nature of these impacts and studies it is suggested that an independent traffic agency conduct new studies to provide data and a report to either verify or not verify the Kimley Horn studies, a "second opinion" for all intents and purposes is needed.

b. Cumulative projects: Refer to Attachment A - "Traffic Study Analysis of Data 2018" conducted by Kim Shultz. The analysis uses the traffic data from the traffic the Saratoga Estates (Attachment B), the Town Center Apartments (Attachment C, Attachment D) and the new updated Saratoga Retail DR-R 18-0001 (Attachment E) and inputs the data into one Microsoft Excel spreadsheet. The purpose of this exercise is to show the varying outcomes of each projects data in one document for comparison purposes. Ms. Shultz listed each projects study tables and subsequent results. This cumulative analysis does not include the impact of the traffic that will be generated by connecting Saratoga Way to Iron Point Road as there appears to be no information regarding this issue in any of these studies.

   In Summary, the combined cumulative projects for 2035 even with the mitigation suggested says the impact will generate a LOS F for the Saratoga / EDH Blvd intersection as well as the Latrobe Road / Town Center / Post Street intersection. The traffic impact studies for Saratoga Estates and the Town Center Apartments were conducted prior to the updated study for the DR-R 18-0001 and the cumulative outcomes are still LOS F for the two intersections. Further study by an independent second agency is needed.

c. Critique of Proposed Mitigation: The proposed mitigation of the project relies on the mitigation of two other projects that have been approved by the County of El Dorado: Saratoga Estates and the Town Center Apartments, as well as mitigation by El Dorado County's planned Capacity-Enhancing Roadway Improvements.

The proposed project relies on the mitigation of another project (Attachment C – TC APTS – LOS F Saratoga Transportation). However the mitigation for the Town Center Apartments is not scheduled to occur until sometime in the future, "Additionally, the County's annual Intersection Needs Prioritization Process will identify if the intersection triggers a LOS impact prior to 2035. Should the LOS become unacceptable, the potential intersection improvements can be added, by the Board of Supervisors, to the CIP as funding becomes available." IF the funding becomes available.

The Town Center Mitigation also states, "As the proposed project is not a single-family residential subdivision, the second paragraph under Policy TC-Xf is the guiding policy for mitigation of this project's impact. Therefore, payment of Traffic Impact Mitigation (TIM) fees will satisfy the project's fair share portion of the improvement project. Mitigation Measure C-TRANS-1 is set forth below to ensure that the project will pay TIM fees to mitigate its impact at this intersection."

The above mitigation scenarios in insufficient and do not meet the standards adopted by CEQA. The arguments above on the failures of the County's mitigation proposal are adopted and incorporated herein. Further, based on representations from County officials, there is no plan to expand Saratoga Way at the site of this proposed drive-through. Any expansion at this specific location would be determined on a further study performed by a different entity. This is wholly improper.

In a lawsuit the 167 Cal.App.4th 1099, Court of Appeal, Fifth District of California, *Gray v. County of Madera* (2008) the court agreed that "the EIR failed to adequately analyze the Projects impacts on traffic because it improperly deferred mitigation measures relating to traffic. We agree." To address their mitigation measure for road improvements the appellants charged among other things that "there is nothing in the mitigation measures that requires Caltrans or Madera County to actually impose impacts" furthermore the court found that "the County made no finding regarding the limitation or the feasibility of the County guaranteeing funding for roadway improvement." The court agreed. "... "the letters show intent to make improvements but no definite commitment on when the improvements will take place." "Furthermore, there is no evidence that the County has a mitigation plan in place involving the improvement or maintenance of the various local roadways because of the increased vehicle traffic. Thus, the mitigation measures relating to traffic impacts are inadequate." El Dorado County General Plan and the accompanying Measure E require:

Policy TC-Xa3

All necessary road capacity improvements shall be fully completed to prevent cumulative traffic impacts from new development from reaching Level of Service F during peak hours upon any highways, arterial roads and their intersections during weekday, peak-hour periods in unincorporated areas of the county before any form of discretionary approval can be given to a project.

Policy TC-Xf

At the time of approval of a tentative map for a single family residential subdivision of five or more parcels that worsens (defined as a project that triggers Policy TC-Xe [A] or [B] or [C]) traffic on the County road system, the County shall condition the project to construct all road improvements necessary to maintain or attain Level of Service standards detailed in this Transportation and Circulation Element based on existing traffic plus traffic generated from the development plus forecasted traffic growth at 10-years from project submittal.

For all other discretionary projects that worsen (defined as a project that triggers Policy TC-Xe [A] or [B] or [C]) traffic on the County road system, the County shall condition the project to construct all road improvements necessary to maintain or attain Level of Service standards detailed in this Transportation and Circulation Element.

High Rate of Speed: In Section 4.7 of the Saratoga Estates FEIR (Attachment J) there is yet another concerning factor, page 2-4 says that Saratoga Way will be a 45mph zone. It is not rational to assume that Park Village Residents will not only have to navigate getting onto a road that will have hundreds and hundreds of more cars, but that those cars will be traveling at a rate of speed that is likely a traffic accident scenario. This situation has also not been studied and needs to be addressed in a full environmental impact report.

Southbound right turn lane: This mitigated feature addresses only the traffic coming from El Dorado Hills Blvd. from Lassen Lane. How does this address the traffic coming from the freeway? This mitigation does not apply to the location that most of the traffic is being generated from which further implies that it won't affect the left turn traffic from EDH Blvd. onto Saratoga, or the right turn traffic from Saratoga to EDH Blvd. The feasibility that this mitigating factor be applied to the major source of traffic is non-existent and therefore this mitigating factor is very misleading and won't alleviate the LOS F traffic.

In Attachment E the DR-R 18-0001 Saratoga Retail states:

M1. Intersection #1, El Dorado Hills Blvd @ Saratoga Way/Park Drive

This intersection operates at acceptable LOS E during the PM peak-hour without the project, and the project results in LOS F. Consistent with the findings of the previous Saratoga Retail Phase 2 Cumulative (2035) Conditions analysis 1, the impacts at this intersection can be mitigated by off-site improvements including optimization of the Latrobe Road coordinated signal system and the restriping of the westbound Town Center Boulevard approach to include one left-through lane, and two right-turn lanes, with a permitted-overlap phase for the westbound right-turns. The El Dorado Hills Town Center Apartments project is responsible for, among other things, the lane designation and signal phasing mitigations described above. This mitigation affects an approach on a privately-owned roadway, and therefore, the improvement should be coordinated with the County and the property owner. As shown in Table 13, this mitigation measure result in the intersection operating at LOS D during the PM peak-hour. Therefore, this impact is less than significant.

M2. Intersection #4, Latrobe Road and Town Center Boulevard

This intersection operates at Los F during the PM peak-hour without the project, and the project contributes more than 10 trips. Consistent with the findings of the previous Saratoga Retail Phase 2 Cumulative (2035) Conditions analysis1, the impact at this intersection can be mitigated by optimization of the Latrobe Road coordinated signal system, along with the following improvements: the restriping of the westbound Town Center Boulevard approach to include one left-through lane, and two right-turn lanes, with a permitted-overlap phase for the westbound right- turns. The El Dorado Hills Town Center Apartments project is responsible for, among other things, the lane designation and signal phasing mitigations described above. This mitigation affects an approach on a privately- owned roadway, and therefore, the improvement should be coordinated with the County and the property owner. As shown in Table 13, this mitigation measure results in the intersection operating at LOS E during the PM peak-hour. Therefore, this impact is less than significant.

The DR-R 18-0001 is relying on traffic mitigation that may or may not happen in the near future and according to case law cited above, this is not acceptable.

Additionally, the proposed signalization mitigation may have it's own drawbacks and further study is necessary to determine if this method of

traffic control will work in this scenario of a left turn from El Dorado Hills Blvd onto Saratoga Way as well as the right turn from Saratoga Way onto El Dorado Hills Blvd. Attachment H - "Traffic Signal Synchronization in the Saturated High-Density Grid Road Network" is just one of a few research studies that indicates traffic scenarios that may or may not benefit from certain types of signalization. If area projects are relying on a type of signalization to mitigate for LOS F traffic impacts it is imperative that this method is proved reliable in this particular scenario.

For example, this particular study states, "Unfortunately, when applied in the saturated HGRN, the performance of these systems has not been satisfactory. When the network is saturated, there is no extra time and space to optimize the traffic signals. Therefore, the regional signal control systems cannot optimize the signal control parameters at the intersections, and the control systems may operate as fixed-timed control systems. In this situation, the traffic system is more fragile and prone to traffic congestion."

"Besides, the signalized intersections are densely distributed, and the accommodation space for the vehicle queues is limited. As a result, if congestion occurs at one intersection, the congestion will cause a domino effect, which may cause the regional congestion in the HGRN. Meanwhile, once it happens, the mobility in the HGRN will be difficult to restore."

It is also imperative that while adding 2700 cars per day to the existing traffic pattern, in addition to the two proposed projects traffic impacts, and the extension of Saratoga Way to Iron Point Road in Folsom, that while consideration is given to adding a fast food drive thru such as Chik Fil A, consideration must also be given to Park Village and its residents who will feel the brunt of all of these traffic impacts.

There are more traffic impact issues that this document has not addressed. Should the burden of addressing all the pertinent issues derived from a number of area projects that affect Saratoga Way and Park Village Residents fall to the community? Isn't it the planning departments responsibility to adequately and thoroughly address impacts via a proper Environmental Impact Report?

CONCLUSION:

The residents responsible for this submission have worked tirelessly to present thoughtful and authenticated arguments against the proposed Saratoga Retail Project. It should not be the job of the residents to ensure the Planning Department is adhering to the laws of this County when reviewing applications and presenting findings to the Commission for

consideration. The Saratoga Retail – Phase II revision application failed initially for the same reasons that it now fails: it is non-compliant with the laws of this County. A DRIVE-THOUGH FACILITY CANNOT BE CONSTRUCTED ON THIS LOT AND MEET THE 8 SPECIFIC CONDITIONS ADOPTED BY THE COUNTY AS MANDATORY OBLIGATIONS.

Consistent application and adherence to the laws of this County is crucial. The Planning Department does not have the power to selectively choose which laws it applies to which projects. Instead the mission statement is clear, the Planning Department is tasked with ensuring that all development proposed for this County complies with all LAWS of this County.

Much has been argued about the tenant, Chick-Fil-A, and these arguments are proper and should be considered. In addition, we remind the planning department and commission that once built a drive-through becomes a permanent structure that can be occupied by a number of different tenants. This is important because, a subsequent tenant will likely be open on Sundays, and may be open 24-hours. Accordingly, any mitigation that is adopted based on the tenant occupancy of Chick-Fil-A is improper. Instead, the measure is any drive-through that may operate in that facility, including those that may increase traffic on Sundays and at peak am and pm hours.

In reliance on all of the arguments above, residents respectfully request that this Commission resolve the drive-through issue precluding further applications for this non-conforming use. Accordingly, this Commission is requested to deny the Saratoga Retail – Phase II project with prejudice. In the alternative, a full and comprehensive environmental impact report should be issued.

Planning Department <planning@edcgov.us>

FW: Saratoga Retail Phase 2 - DR-R18-0001 (email 2)

1 message

Brooke E. Washburn <BWashburn@murphyaustin.com> Thu, Aug 16, 2018 at 2:20 PM
To: "planning@edcgov.us" <planning@edcgov.us>

MurphyAustinLogo

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From: Brooke E. Washburn
Sent: Thursday, August 16, 2018 1:13 PM
To: 'charlene.tim@edcgov.us' <charlene.tim@edcgov.us>
Cc: 'Timothy White' <tjwhitejd@gmail.com>; 'John Davey' <jdavey@daveygroup.net>; 'john.hidahl@edcgov.us' <john.hidahl@edcgov.us>; 'jvegna@edcgov.us' <jvegna@edcgov.us>; 'Hilary Krogh - Saratoga' <hilaryd73@gmail.com>; 'Kim S - Camom' <CAmom2345@hotmail.com>; 'Rebecca - neighbor' <rebecca.isbell@ymail.com>; 'Wes Washburn' <weswashburn@yahoo.com>
Subject: RE: Saratoga Retail Phase 2 - DR-R18-0001 (email 2)

Attached, please find pdf documents that are collectively **Exhibit A**, substantial evidence submitted to demonstrate a significant impact to Aesthetics (Section A. of the public comment- previously submitted). Please add these documents to the public record for Saratoga Retail Phase 2 - DR-R18-0001.

Brooke E. Washburn

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From: Brooke E. Washburn
Sent: Thursday, August 16, 2018 12:21 PM
To: 'charlene.tim@edcgov.us' <charlene.tim@edcgov.us>

Cc: 'Timothy White' <tjwhitejd@gmail.com>; John Davey <jdavey@daveygroup.net>; 'john.hidahl@edcgov.us' <john.hidahl@edcgov.us>; 'jvegna@edcgov.us' <jvegna@edcgov.us>; Hilary Krogh - Saratoga <hilaryd73@gmail.com>; 'Kim S - Camom' <CAmom2345@hotmail.com>; Rebecca - neighbor <rebecca.isbell@ymail.com>; 'Wes Washburn' <weswashburn@yahoo.com>
Subject: Saratoga Retail Phase 2 - DR-R18-0001

Dear Charlene,

Attached is public comment submitted by affected and concerned residents with regard to a proposed project (Saratoga Retail Phase 2 - DR-R18-0001). Due to the size of the documentation to be submitted, I will send all attachments under separate cover. Kindly include all comments and attachments in the public record for the project (Saratoga Retail Phase 2 - DR-R18-0001), and submit the same to the commission in advance of the **August 23, 2018**, hearing.

Brooke E. Washburn

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10 attachments

- **values5.pdf** 63K
- **values4.pdf** 206K
- **Values3.pdf** 48K
- **Value2.pdf** 565K
- **Values1.pdf** 270K
- **crime4.pdf** 36K
- **crime3.pdf** 32K
- **crime 2.pdf** 29K

CRIME.pdf
62K

Steinbacht_ Aesthetic Zoning.pdf
785K

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PC Rcvd 08-16-18

https://homeguides.sfgate.com/brings-property-values-down-6658.html

SFGATE

The Effects of Commercial Property on Residential Value

Written by Ryan Cockerham; Updated July 26, 2018

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If you are in the process of buying a home or may be considering selling your home in the not too distant future, you have a vested interest in the current state of the housing market. Although a myriad of factors can affect housing prices, it is a commonly held assumption that the presence of commercial property (or the promise of future commercial development) can significantly impact the value of nearby homes. The nature of this impact can vary widely. Whether or not home prices rise or fall due to commercial property can depend on many variables, including the demographic that the commercial property targets, the size of the property and the anticipated number of customers it will attract, among others.

Congestion and Traffic

One of the biggest concerns that homeowners have when commercial developers begin purchasing plots of land close to them is whether or not the projects planned will significantly increase the amount of vehicle traffic in the area. A surefire way to hurt property values and reduce buyer interest in neighborhoods is to make them hard to access due to constant traffic.

A significant increase in the number of individuals near a residential area could also deter new parents who may be seeking a neighborhood that is safely isolated from denser areas. There are, of course, exceptions to this rule. Particularly in a city with a high population density, such as San Francisco, the presence of shops, restaurants and other commercial establishments could provide a boost in property value for nearby apartments, particularly if the commercial property caters to an affluent demographic.

Public Transportation

Residential properties in urban areas have been found to enjoy a boost in property value if they are located near transportation centers, such as train stations or San Francisco's BART system. Ultimately, this is due to the level of convenience these services provide. In situations where residents are unlikely to have their own form of transportation, such as a car, easy access to public transit can markedly increase demand for an apartment or condo in a prime location.

The Impact of Culture

Commercial properties can provide an ambiance and unique cultural atmosphere that add an indefinable "polish" to an area, which attracts residents willing to pay higher prices for residential properties. With that in mind, it is quite likely that a collection of quality restaurants, clubs and shops may raise the property value of apartments and homes throughout the area in general. Of course, it goes without saying that the exact nature of the commercial properties will determine how the value of residential units is affected.

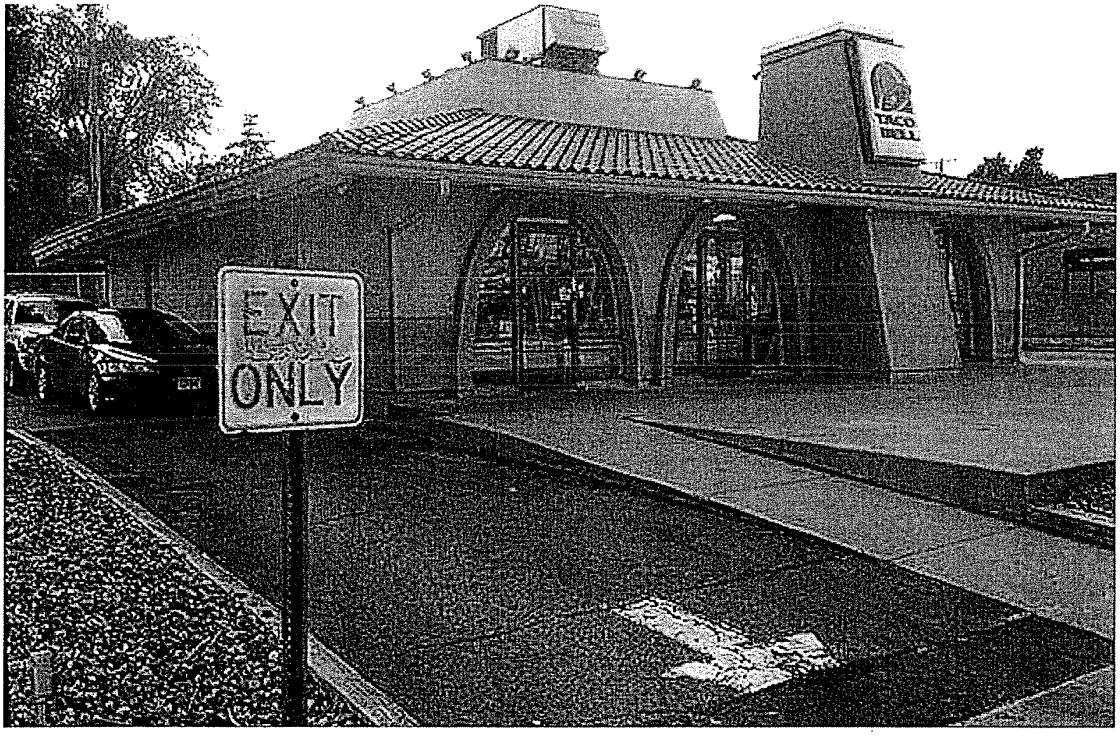
HTTPS://WWW.MINNPOST.COM/CITYSCAPE/2015/08/INS-AND-OUTS-DRIVE-THRUS-AND-WHY-THEY-RE-BAD-CITIES

MINNPOST

CITYSCAPE

The ins and outs of drive-thrus, and why they're bad for cities

By Bill Lindeke | 08/28/15



MinnPost photo by Bill Lindeke

The Snelling Avenue Taco Bell: Drive-thrus are popular but also cause a lot of problems, particularly for people trying to live or walk near one.

In a way, the fast-food drive-thru might be the peak of American civilization. The ability to stop, order anything you want and have it handed to you within minutes, without even having to put your car in park, is nothing short of a miraculous testament to modern technological privilege.

But drive-thrus also cause a lot of problems, particularly for people trying to live or walk near one. As cities like St. Paul try to become more walkable, people are looking more critically at the complexities of the ubiquitous drive-thru.

Families love them, bikes do not

These days, cities like St. Paul are doing their best to limit drive-thrus through mixed-use zoning, which explicitly discourages "auto-oriented uses" like drive-thrus, car repair shops, and large surface parking lots. (Currently, drive-thrus in mixed-use "traditional neighborhood" zones require conditional use permits from the city, which allow city staff to alleviate their impacts.)

Changing the drive-thru culture does not come without a fight. (See, for example, my earlier Cityscape column on strip malls, where drive-thrus were often a sticking point with mall developers.) The appeal of drive-thrus is probably greatest for parents driving with small children, when getting into and out of the car is a big chore.

"Starbucks' drive-thru was a lifesaver when I was a mom with a very fussy baby," Sarah Beilke Champe told me. "Sometimes it was the only interaction I had with an adult during the day."

On the flip side, drive-thrus can be inaccessible to anyone not in a car. Many fast-food restaurants close their walk-in restaurants late at night, while keeping their drive-thrus open (sometimes 24 hours). This practice actually prompted a lawsuit against a local White Castle back in 2009, when a woman on an electric scooter argued that drive-thru-only service amounted to discrimination.

(I've heard lots of stories of people riding bikes or walking dogs going through drive-thrus, but this is mostly just for banks or pharmacies.)

Never-ending nuisance of late-night hours

The worst-case scenario for an urban drive-thru has to be the Snelling Avenue Taco Bell, which because of a historical accident is pushed up right next to a residential neighborhood.

Because its original permit dates back to 1973, when the company was called Zantigo, the city has almost no regulatory leverage over the restaurant. This was before the modern drive-thru existed, and well before the emphasis on late-night hours, so the restaurant's "special use permit" came with no strings attached — leaving the city and neighborhood with few controls over things like hours, noise levels, or security concerns.

The Taco Bell drive-thru debate came to a head this summer as the company proposed to rebuild the decades-old building and redesign the drive-thru, which would require a "conditional use permit" from the city.

"The whole theater of the drive-thru experience is pretty fascinating," Kristine Vesley, who lives directly behind the Taco Bell, told me. "People love that ritual of pushing the speaker button and hearing the tinny worker voice asking them what they'd like to order. They love inching along in the line bopping in their seats and drumming on the steering wheel. They love the disembodied hand giving them a bag of greasy food."

But in their public comment to the city, the closest neighbors, the Vesleys, offered extended documentation of the noise, trash and passed-out people generated by the late-night drive-thru. Because late-night drive-thrus don't offer bathrooms, many people simply urinate in the alley, and the Vesleys' documentation of years of nuisance are neatly categorized according to type of loud car, or the politeness of the public urinator. The couple also included years of correspondence with city regulators and staff, trying in vain to rein in the hours and nuisance.

MinnPost photo by Bill Lindeke

Cars stack up in the Taco Bell drive-thru during the day.

After weeks of deliberation and back-and-forth between Taco Bell and the city's Zoning Committee, the issue came down to a few details: The city wanted hours reduced to 1 a.m. on weekends, and a security guard on site, but the company balked at the proposal. In the end, profits outweighed politeness, and Border Foods withdrew their application.

"We're really disappointed that Border Foods was such a sore loser," Kristine Vesley told me after the final hearing. "A 2 a.m. closing was their line in the sand, even though other similarly situated Taco Bells close at midnight during the week and 1 a.m. on weekends. We objected to the intensity of this drive-thru use in this particular location, more like a wild after-party with nine cars idling, full of occupants yelling and radios blaring and horns honking — open 22 hours per day, and only

because of a flukey old permit. Having this Taco Bell drive-thru operating for five to six hours per day without the building and rest rooms open is just stupid."

Blight on walkability

Another dynamic is that drive-thrus damage walkability because they require so many curb cuts cut into the street. For example, just past downtown along Saint Paul's West 7th Street, hotels and apartments are quickly rising in long-empty parking lots.

The new development prompted questions when, last year, a drive-thru proposal emerged that would have transformed an old Dairy Queen into a drive-thru Brueggers/Caribou hybrid. It would have required two loops of car lanes surrounding a small, one-story restaurant.

"We had purposely rezoned that part of West 7th Street," Adam Yust, who is on the board of the local neighborhood group, told me. "Across the street from the site, there are amazing historic buildings, and we wanted more of that on West 7th. The board was unanimous, and made a motion to deny approval because it was the complete opposite of our long-term plan and visions for the corridor."

MinnPost photos by Bill Lindeke

The proposed Starbucks site

According to Yust, the more that driveways are built up and onto the sidewalk, and the more cars are driving over them, people will be less likely to walk around.

"The future of West 7th is not a car-oriented street," Yust said. "If you're walking down the street, you don't want to walk through two cut-thrus within 30 feet of each other. Plus they were asking for more parking spaces than the minimum. They could have put a two-story building there, and that would have been fine. But, it was clear that they wanted to keep the neighborhood paved over."

After meeting resistance from the local neighborhood group, the developer withdrew the application. To this day, the Dairy Queen remains empty, and the land is used mostly for Xcel Center event parking.

A fit for marginal spaces?

Not all drive-thrus are immediately shot down. The Southeast corner of Snelling and Marshall is an awkward space, where a drive-thru might be the only reasonable fit. For the last few decades, the site has housed a bike shop, a (long-shuttered) car-repair place, and a drive-thru coffee kiosk where a lonely employee sat in a tiny box distributing hot coffee to passing drivers.

But as the corner changes with the new Snelling Avenue bridge and new mixed-use developments just blocks away, plans for the oddly shaped parcel have prompted debate in the neighborhood. This summer, a developer approached the neighborhood with a proposal for a drive-thru Starbucks.

"Many of us [in the neighborhood] feel that a drive-thru does not belong there," Anne White, who chairs the land use committee for her neighborhood group, told me. "This a place where we're trying to get transit-oriented development, and to make it more walkable. This is just completely in the wrong direction. It's a suburban model but apparently it increases their profit by 40 percent over not having a drive-thru."

The primary concern for the neighborhood group is that the drive-thru proposal won't do anything to improve the surrounding neighborhood, and that it might cause massive traffic headaches at the busy intersection. Indeed, the developer has gone through multiple revisions with MnDOT and the city, trying to figure out just how many left-turn lanes and how much "stacking" (i.e. spaces where cars can idle as they queue up) the spot will require.

"This site has been a mess for 20 years," Anne White said. "Its not a beautiful location by any means, its east side and south side have great big retaining walls [and] essentially people voted in favor. They felt that Starbucks had done as much as they can do to make this more palatable, and that we should let them go ahead."

In the end, the committee members held their noses and voted to approve the Starbucks' plans, citing the awkwardness of the site for more walkable developments. The plan will go to the city for consideration later this year.

https://www.washingtonpost.com/archive/opinions/1985/06/23/fast-food-in-our-neighborhood/47d17bce-557b-455b-948e-905b0acaf32a/?noredirect=on&utm_term=.73dc422f5857

The Washington Post

Fast Food? In Our Neighborhood?

June 23, 1985

From Anacostia to Alexandria, residents are fighting fast-food franchises. Are these shops a nuisance or a convenience? We present some views on the subject.

Washington is one of the last major cities to exert control over proliferating fast-food establishments. Without effective regulations and restrictions, such as those passed recently by the D.C. Zoning Commission, the city and its residents will be the big losers.

Fast-food restaurants don't mesh with the fabric of city neighborhoods. These places are objectionable because they create tremendous traffic congestion and horrible parking problems in shopping districts designed for pedestrian use. The high volume of traffic results in loud noise and crowds. The restaurants generate vast amounts of garbage and spread trash throughout the surrounding residential area.

Moreover, the designs of many of these establishments are completely incongruous with the architecture of Washington's neighborhood shopping districts. The garish lighting and gaudy trademark displays, deemed so necessary to attract large audiences, add to their intrusive presence in inner-city shopping neighborhoods.

Also, fast-food restaurants have a propensity to multiply. The industry itself testified before the Zoning Commission in the fall of 1983 that one fast- food establishment tends to bring more into the immediate neighborhood. The industry contends that an aggregation of these places helps the business of all. This is not a surprising argument. Even a cursory view shows that these establishments tend to group together. This only adds, however, to the noise, the crowds, the traffic, the trash and the offensive lighting.

These places tend to cheapen a neighborhood, drive out other businesses and lower residential property values. Fast-food chains have the market power to establish themselves in a neighborhood thus depriving residential shoppers of the much-needed small retailers offering local services.

For these reasons, the industry's arguments that its restaurants raise taxes and create employment are quite simply false. They drive out local businesses, have no net effect on employment and actually lower property values. Further, they cause a flight of capital from the city. Large franchises send a large amount of profit out of the city back to corporate headquarters. Local shopkeepers, to the contrary, spend and reinvest their money right here at home.

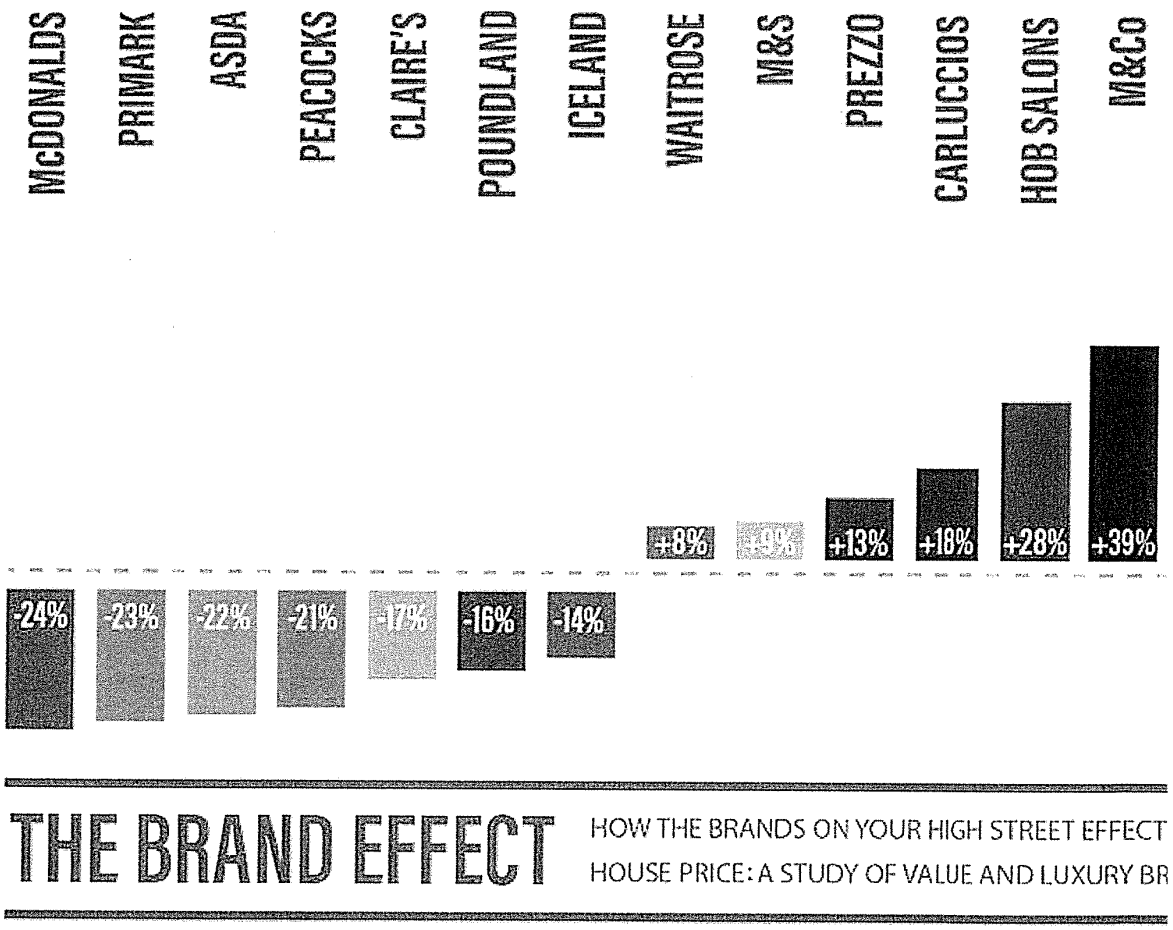
Consequently, it is essential that the city of Washington effectively control and regulate fast-food establishments. This does not mean that they have no place in certain areas of the city; they do. But fast- food restaurants have no place in local shopping districts and in areas next to residential neighborhoods. Otherwise, the proliferation of these places will transform this city into the nightmarish "strips."

https://www.fastsaletoday.co.uk/blog/living-near-mcdonalds-devalue-house-price-24/

Fast Sale Today

Living near a McDonalds lowers your house price by 24%

26th May 2016 by Louis



We conducted a study in partnership with journalistic.org to find out how the brands on your high street can affect your house price. Our analysts looked at 21 different brands on 27 high street towns, alongside Land Registry house price data to determine the brands that influence your house price.

House price growth has seen a steady year-on-year increase since 1995, with the exception of the 2007-2008 property market crash. Ever since the housing market has recovered handsomely, as UK house asking prices at an all-time high of £307,033 according to Rightmove's house price index for April 2016.

There are, of course, many factors that we originally associate with higher and lower house values. There's the standard physical features like the number of bedrooms, bathrooms and available floor space. There are plenty of estate agent-made categories that are said to influence your house asking price like transport links, quality of nearby schools, noise levels, crime rates and even the name of your road. So we thought we'd investigate if there is a hidden effect from the brands that occupy your high street.

What if the type of shops and brands that you live nearby actually influence your house price?

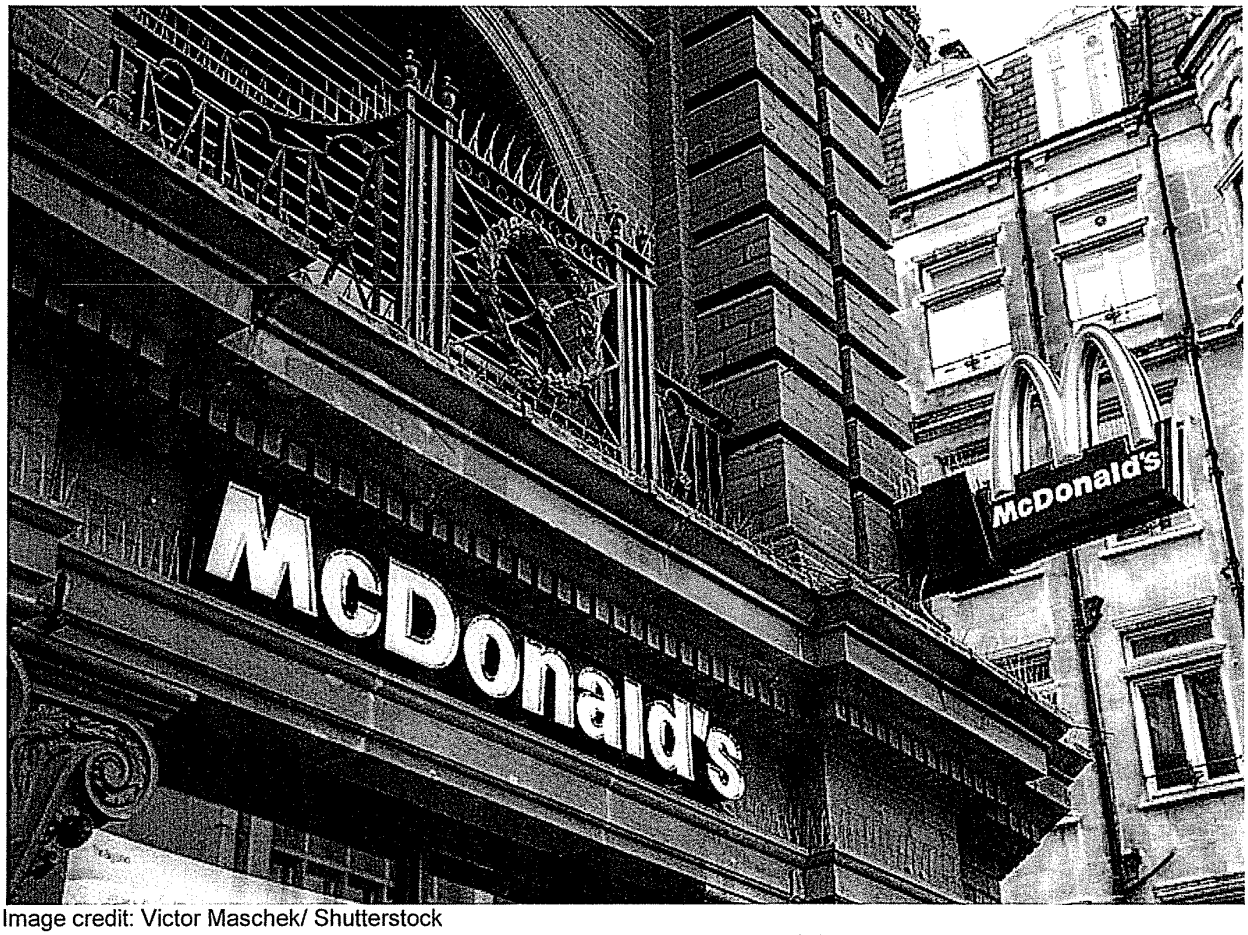


Image credit: Victor Maschek/ Shutterstock

Here at FastSaleToday we conducted an in-depth study of 21 brands and the average house prices of 27 towns with high streets. The results showed that premium restaurant brands, specifically Carluccio's, Prezzo and Zaza all had a positive effect on your house price. With living near a Zaza creating a whopping 42% rise above average house price values. This finding was linked with the

favourability of such restaurants. People want to live near high-end restaurants and will pay a premium to have them on their doorstep. It was also found that both M&S and Waitrose had a positive effect on house prices of between 8 – 9%. This finding was not of surprise as previous studies have shown that a 'Waitrose effect' may exist. That living near the premium supermarket can increase your house value by up to £40,000. So our results further confirm the existence of this phenomenon, and provide more scope that indicates a 'high-street brand effect' where other premium luxury brands are more likely to increase your house price and where there are higher concentrations of value brands, housing areas in close proximity experience lower than expected average house values.

Another interesting finding was that living near British clothing company M&Co can increase your house price by up to 39%! We were surprised to discover this, as the clothes store was established in 1834 and has been on the high street for many years. But we didn't expect the store to have such a positive effect on house prices, however, perhaps the retailer held value due to its strong heritage.

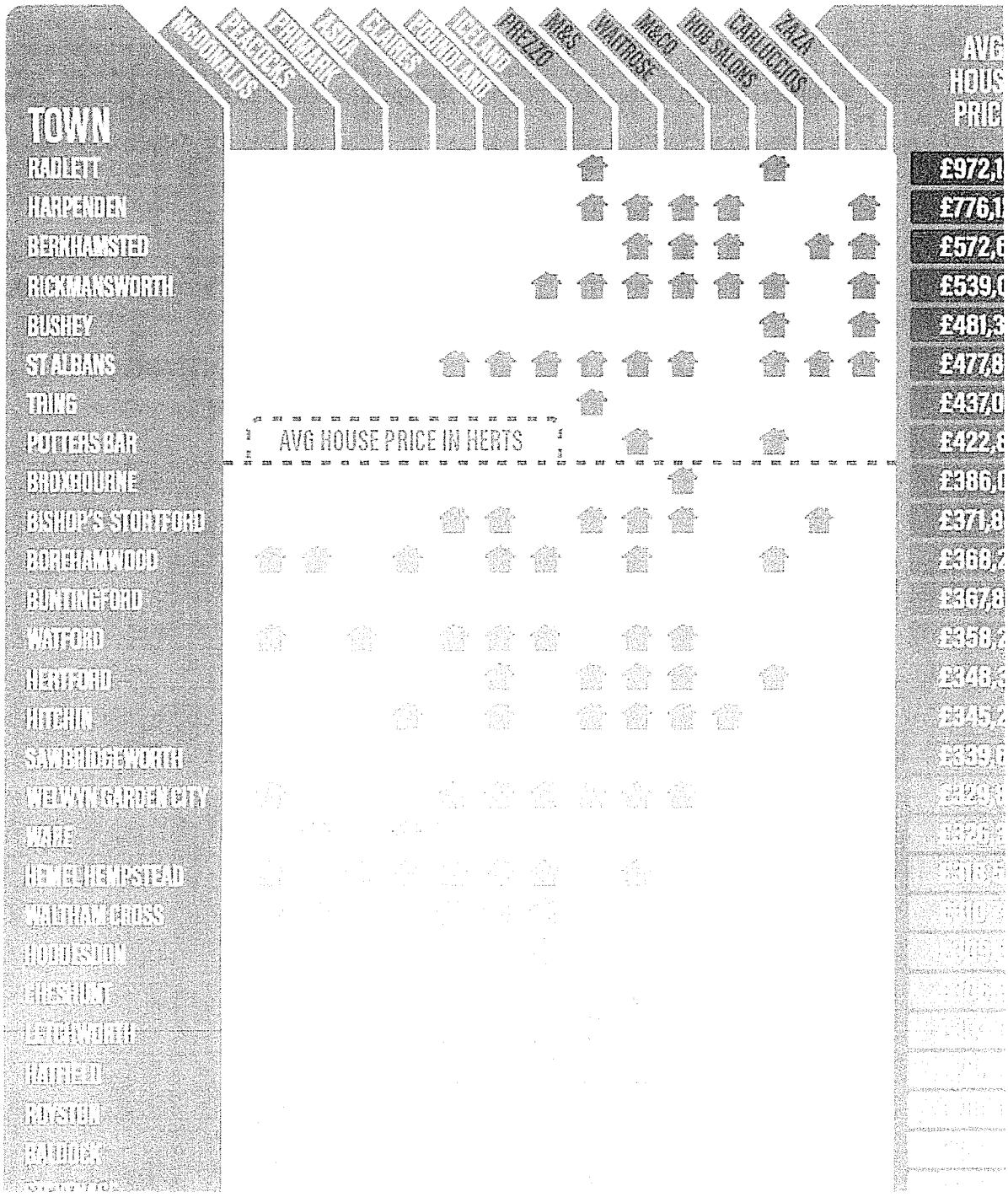
Our research showed that value brands such as McDonalds, Primark, Asda and Peacocks had an adverse effect on your house price in comparison to luxury brands. The above mentioned brands had between a 21 – 24% decrease on your average house price if you were within walking distance of the stores.

There were exceptions to the rule where some premium stores and value brands occupied space on lower than average house price high streets such as Prezzo, M&S, Poundland and Iceland. But the general trend was overwhelmingly significant.

Here is a graph to represent the concentration of high-street brands and average house price

THE HOUSE PRICE BRAND MATCH

THE EFFECT OF BRANDS ON AVERAGE HOUSE PRICE IN HERTFORDSHIRE



Please feel free to share the graphs and content on your website, on social media and anywhere else.

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The price of access: capitalization of neighborhood contextual factors

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Abstract

Background

Methods

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Background

Neighborhood context, defined as the physical and social attributes of a neighborhood, is correlated with health [1]. For instance, better relative access to healthy food and physical activity (PA) resources within a neighborhood is associated with lower body weight at the individual level. This is likely because better access lowers the time required to access healthy food and PA [2-6]. However in most neighborhood context studies, the association between health effects and context are estimated assuming that locational decisions by individuals are random, which leads to bias [7,8]. An important and helpful theory from urban economics has been ignored in this literature: the possibility that the health benefits of local access to healthy food/PA, and of better neighborhoods generally, may be capitalized into, or included in, higher housing values. Likewise, proximity to health-compromising features, such as fast food outlets, may be negatively capitalized, or discounted in terms of housing values or rent.

Capitalization can be thought of as evidence of preference, at the aggregate level, for a given neighborhood and its attributes as compared to alternative neighborhoods. Housing price models are bid models. For instance, if a neighborhood acquires an attribute, like a redeveloped waterfront, its increased desirability will encourage higher bids for the homes in that neighborhood, leading to higher costs for buyers to live there. With capitalization, 'premiums,' or the portion of the housing price which is attributable to that locational feature, may be required for access. Homes can also be 'discounted' (receive a negative premium) for features negatively related to health, indicating underlying preferences for health by those willing to pay for access.

It is acknowledged that income and health are highly correlated [1]. The paradox is that if access to "better" neighborhood contextual factors is capitalized, income, net of housing costs, will be reduced, which might lower health outcomes. Therefore, the overall effects of contextual factors on health is ambiguous. Further, if neighborhood contextual factors are shown to be capitalized, this demonstrates the extent to which locational decisions are not random. Neither issue has been given sufficient attention in the contextual factor literature.

Two economic theories suggest that housing markets capitalize the benefits of neighborhood features. First, von Thünen theorized in the early 19th century that land values are a function of the local area's attributes, particularly, access to the center of the city, rather than the intrinsic value of the property in isolation [9]. Second, the Tiebout model of the 1950's asserted that people sort themselves among localities in order to find their utility-maximizing mix of government services, many of which affect health, and local taxes [10]. Thus, people with similar tastes and similar norms, including 'like-mindedness' over health issues, are likely to sort together.

Empirically, 'hedonic' price models have been used to estimate the level of capitalization of local attributes and amenities. For example, if two identical houses on two identical lots in different areas of town are priced differently, differential local contextual factors, like schools or crime level, may explain the difference in price or capitalization. Hedonic models have been used to estimate the capitalization of better local schools [11], of relative crime avoidance [12], and of relative environmental advantages such as clean air [13]. However, studies of capitalization in the neighborhood context literature do not exist.

We address this gap in the literature by estimating the association of neighborhood contextual variables–particularly, health-related neighborhood contextual variables–and housing values, using the third wave of data from the National Longitudinal Study of Adolescent Health (Add Health), reflecting the years 2000-2001. In our hedonic regressions of housing values by income quartile, we demonstrate that health-related attributes such as supermarket density are capitalized.

Neighborhood context and health

Health-related neighborhood attributes have received particular attention in sociological and economic literature as correlates of health, yet, as mentioned, have not been investigated explicitly in models of housing capitalization. For instance, access to healthy food has been linked to better diets and lower obesity rates. There is extensive literature documenting that poorer and ethnic minority neighborhoods have fewer supermarkets per household [14-23]. Supermarkets often provide higher quality food products and offer lower food prices than other food outlets [22,24]. Increased availability of chain supermarkets is significantly associated with lower adolescent BMI and overweight, while greater availability of convenience stores is significantly associated with higher adolescent BMI and overweight [23]. According to Powell et al. (2007), the link between supermarket availability and weight is often indirect, with studies often simply demonstrating that availability is associated with consumption [25], or that availability is associated with diet quality [26].

There is also extensive literature documenting that particular physical environments are positively associated with PA levels [4-6]. Neighborhoods with higher income and lower poverty have more of certain PA outlets, including parks and bike path lanes (though not more public pools or beaches) [27]. Lower income individuals are more likely to perceive limitations to PA in their neighborhoods, including safety, gangs, traffic, and affordability [27,28]. Regular PA, in turn, is associated with reduced obesity [27,29].

The bid model

The von Thünen bid model can be illustrated as follows. Suppose everyone living in the urban space must travel downtown for work. Commute times vary by location of residence, and people place different values on time, and that value is correlated with wages. Suppose that a person values time at $10 an hour, and would save 20 hours per month commuting downtown for work by moving from his current location to location *X*. What would he bid for the move? He would bid up to $200 ($10 times 20 hours) more than his current location. This may be enough to displace the person currently at location *X*, who may place a lower value on time. Alternatively, the person at location *X* may match the higher bid. According to the bid model, people bid and sort until an equilibrium emerges, where no one is induced to outbid people at other locations. Note that not everyone must move for the equilibrium to emerge.

All else equal, land rents or prices tend to increase towards the center of the city because of lowered commute time costs.[1] This equilibrium pattern of rental and land prices is called a rental gradient. Rental gradients can also shift up or down because of characteristics other than time needed to travel to a nearby location. These include local area crime, pollution, school quality, etc. For instance, if crime avoidance is valued by the potential mover in the previous paragraph, he would bid less than $200 if location *X* has higher crime than his current location. If crime is lower at location X, he would bid more than $200. Note that the process of valuation is subjective, such as with the perceived threat of crime. Note also that rents and prices for homes are highly correlated, spatially; there are few places with high housing rents and low housing prices.

Note that income limits the ability to bid, regardless of preference for a local attribute. For instance, low-income people may highly value education for their children, but not be able to afford to live in areas with the very best schools. However, qualities such as crime level and school quality are reflected by a range of levels, rather than in binary variables. Therefore, low-income families may be willing, and able, to pay more to live in a location with average schools rather than living in an area with worse schools.

In this paper, we apply von Thünen's bid model by testing whether access to local food and PA amenities that are positively related to health are shown to be valued positively in terms of housing prices, i.e., whether they are associated with an upward shift in the gradient, and by how much; and whether amenities negatively related to health are valued negatively in terms of housing prices. Because poorer people are likely to be outbid for access to locations with the absolute best access to healthy food and PA amenities, we stratify our analysis by income level of the neighborhood.

Go to:

Methods

Data

Our data are from the third wave of data from the Add Health data set, a longitudinal study based on a nationally representative sample of adolescents in the United States, initially drawn in the 1994-1995 school year. In our study, we utilize data from Wave III of Add Health, in which a majority (73.13%) of the original Wave I respondents were re-interviewed between August 2001 and April 2002, when these participants were between 18 and 26 years old [30]. We would have liked to have taken advantage of the full panel of Add Health data. However, our capitalization and neighborhood context measures were only available at Wave III.

We chose the Add Health data set for this analysis for several reasons. Most important, the neighborhood amenities in the Add Health data are counted with respect to a distance, either straight line or street network, from an individual's residence, at one of four levels: block group, tract, county, or state. We chose the block group level (keeping only one observation, randomly chosen, per block group); and used the street network distance, based on an 8 kilometer search, for the counts. A block group is defined by the U.S. Bureau of the Census as a "subdivision of a census tract... [and] the smallest geographic unit for which the census bureau tabulates sample data. A block group consists of all the blocks within a census tract with the same beginning number" [31]. Block groups average about 1,000 inhabitants.

U.S. Census data also counts amenities such as supermarkets and fast food outlets at the block group level. However, it does not base its counts on street network distances from each individual's residence, but rather presents counts in summative fashion for the block group as a whole, regardless of the location of individual's residences within that block group. Hence, the Add Health data, while used here at the neighborhood level only, is inherently individual-focused. Measuring counts based on travelable streets ties in directly with the von Thünen bid model, reflecting the time and effort a resident would practically spend to reach the desired neighborhood amenity, such as a supermarket. In analyzing neighborhoods or block groups rather than persons, we specified school ID as the primary sampling unit, and specified region as the strata variable, as indicated in Add Health weighting instructions. We used Stata's subpopulation weighting techniques when estimating models separately by income quartile.

We also found that the Add Health data have good representativeness in terms of sampling. Add Health's contextual data sample included low-population, rural areas with as few as 1900 persons per county at Wave III. For comparison, the American Community Survey (a yearly counterpart to the decennial U.S. Census) is less representative in terms of places represented in the data, being based on a more restrictive standard of 20,000 or more persons in a given area [31]. Additionally, the Add Health data contain health outcome variables that, in a next stage of this research, can be easily linked with the home values and neighborhood amenities, to determine the influence of these on health.

Finally, we chose to analyze data from earlier in the 2000s because this reflected a period just before the housing bubble, and then the subsequent housing crash [32]. Either event could bias attempts to correlate attributes with housing values.

The use of the data has been approved by the Committee for the Protection of Human Subjects at the University of Texas Health Science Center.

Measures

Density

We based population density on a Wave III contextual data item marking persons per square kilometer at the block group level. This variable should be correlated with distance to the urban center, making it essential in determining housing value in the von Thünen sense [9].

Per capita income

We based per capita income on a Wave III contextual data item marking per capita income at the block group level. In Tiebout models, similar people sort together [10], so we would expect wealthier people to pay a premium to live near other wealthy people. In addition to using this item as a predictor of median housing value and rent, we also used it to divide our sample into quartiles based on block group per capita income. This was done using the PROC RANK procedure in SAS. Dummy variables created from this procedure (named 'first' for the poorest, 'second', 'third' and 'fourth' for the wealthiest) were used as subpopulation markers for Stata's subpopulation command, which allowed us to estimate models separately by income quartile group.

Median year built for housing units

We based median year that housing units in each block group were built on a Wave III contextual data item ranging from 1939 (reflecting a build year of 1939 or earlier) to 1999.

Median home value

We based median home value on a Wave III contextual data item marking median home value of owner-occupied housing units at the block group level, based on Census 2000 data. Medians were preferable because this value was most representative of each block group, without undue influence by markedly higher or lower home values for a small number of blocks in the group. Utilizing values for owner-occupied homes excluded homes for which the owner would not be using its nearby amenities, such as rental units, vacation homes, or seasonal residences.

In the original Add Health data, 95% of the home values ranged from $16,700 to $935,700. A small number of cases had values of less than $10,000 or greater than $1,000,000. We eliminated cases that fell into these lower and higher categories due to their extremity and the crude grouping of these cases in the Add Health data. This provided us with a representative range of values without excessive extremes, and with relatively precise measurement. Finally, we divided these home values by 1,000 to yield a variable with a scale that was reasonably matched with the predictors, allowing for interpretable beta weights.

Densities of food and activity resources

We based Wave III densities of supermarkets, fast food chain outlets, cooperative natural/health food stores, convenience stores, fruit/vegetable markets, and activity outlets on Wave III neighborhood resource data items marking counts of these resources within eight-kilometer network search units. Activity outlets included instructional facilities, membership facilities, outdoor facilities, public fee facilities, parks, public facilities (such as beaches and pools), schools, YMCAs, and youth organizations (such as boy and girl scout organizations). These resources had been categorized by Add Health staff according to Dun and Bradstreet's 2001 primary Standard Industrial Classification (SIC) codes and keyword searches within the company name and trade style fields. While the Dun & Bradstreet data have had their accuracy questioned, recent literature has shown that the predictive validity of the D&B food resource data is "good" and comparable to competitor data such as from InfoUSA and Department of Health and Environmental Control data [33,34].

To convert counts into densities, we divided the counts by Census tract population (a tract being a small, relatively homogeneous subdivision of a county, larger than a block group) [31]. To put the density values on a scale similar to other variables in our models, we then multiplied these values by 1,000.

Total crime

We based total crime on a Wave III item giving an index of total crimes reported (as opposed to arrests made) per 100,000, at the county level.

Proportion college educated

We based proportion of persons with a college education on a Wave III variable marking the proportion of persons at the block group level who are 25 years or older and have a bachelor's degree or more. In Tiebout models, similar people sort together [10], so, as with income, we would expect college-educated people to pay a premium to live near similar people.

Region

Because real estate varies by region, we included dummy variables (1=yes, 0=no) for whether the block group was in the West, the Midwest or the South, with the Northeast as the omitted variable.

Activity by crime interaction

Research has shown that in high-crime areas, parents are more apprehensive about using parks and trails [35], and value access less because they are seen as hosting criminal activity [12]. Prior to modeling, we also created a Crime by Activity Resource Density interaction term, having centered the Total Crime and Activity Resource Density variables prior to cross-multiplication. The interaction term was included in all specifications of our model, along with the centered versions of the component terms.

Analysis

Our initial sample consisted of 7,870 unique block groups. Prior to analysis, we performed natural log transformations on the population density, activity density, and five food outlet density variables in order to account for the highly skewed nature of these variables. After these transformations, all variables showed reasonable skew statistics.

Next, we checked our data for outliers on the variables to be used in our regression models. We applied a conservative 6.0 standard deviation cutoff for the removal of outliers from our sample. Removal of cases with absolute values of greater than 6.0 standard deviations from the mean on one of more predictors reduced the sample to $N = 7{,}845$, and removal of additional cases with extreme values for home prices reduced the sample to its final size of $N = 7{,}817$.

Our hedonic price model is of the form

$$Y_b = \mathrm{XH}_b\beta_b + \mathrm{XN}_b\beta + u_b, \quad (1)$$

where Y_b is the housing value for census block b, XH_b are health-related attributes of that location, including access to food, etc., XN_b are non-health-related attributes of that location, including access to the center of the city (density) and age of the housing stock. Finally, u_b is the error term.

We estimated this model first across all block groups, then separately by income quartile. As noted, we included Median Income as a predictor in the model even when running models separately by income quartile. Our reasoning is that even among income quartiles, there is still significant variation on the Median Income variable. We also ran models both with and without the natural/health food and fruit/vegetable market density variables, reasoning that these variables could be collinear with the supermarket density variable.

Go to:

Results

Table 1 shows the means and proportions employed in our analysis.

Table 1

Weighted means and proportions

Variable	Mean, Proportion	(Std. err.)
Median housing value, block group level	135.961	(5.430)

Variable	Mean, Proportion	(Std. err.)
Population density, block group level	2765.224	(313.526)
Proportion 25+ with a college degree, block group level	0.245	(0.009)
Per capita income, block group level	20091.347	(447.524)
Median year housing built, block group level	1967.772	(1.025)
Northeast (1=yes; 0=no)	0.126	(0.022)
West (1=yes; 0=no)	0.264	(0.036)

Variable	Mean, Proportion	(Std. err.)
Midwest (1=yes; 0=no)	0.233	(0.037)
South (1=yes; 0=no)	0.377	(0.042)
Supermarket density	5.624	(0.413)
Fast food (chain) density	22.804	(1.427)
Natural/health food store density	3.217	(0.171)
Convenience store density	36.723	(2.554)

Variable	Mean, Proportion	(Std. err.)
Fruit/vegetable market density	2.506	(0.194)
Activity resource density	152.578	(8.837)
Crimes reported per 100,000, county level	4930.496	(155.710)
Activity resource density by Crime interaction	45.661	(62.847)
N	6,882	

Open in a separate window

Note: Units for Median Housing Value were thousands of 2001 dollars. Units for Population Density were persons/km^2. Units for Per Capita Income were 2001 dollars. Units for resource density variables were 8 km count/tract population X 1000.

Table 2 shows the results for the hedonic regression model for housing values estimated across all income quartiles. As expected, block group level income is correlated with housing price, as is percentage of adults aged 25 and older and with college education. This is in accordance with predictions of the Tiebout model, where wealthier people pay a premium to sort together.[2] This would as be predicted if there is a premium for prestige in a neighborhood, or hard to observe benefits that accrue from living near wealthier, educated people. All else equal, housing costs more in the West and less in the South and Midwest. Also as expected, the crime rate is negatively associated with housing value, and block group level density is positively related to housing value. As mentioned earlier, population density is a proxy measure for distance to the center of the urban space in the von Thünen sense [9]. The greater the density, the greater the housing price because, typically, this is closer to the central city relative to less dense areas, thus affording greater access.

Table 2

Hedonic regressions predicting median home value, full sample of census blocks

Variable	Coef	(Std. err.)	Coef	(Std. err.)
Natural log of density, block group level	7.274**	(1.490)	8.451**	(1.729)
Proportion 25+ with a college degree, block group level	85.406**	(11.347)	71.592**	(11.981)
Per capita income	0.005**	(0.000)	0.005**	(0.000)
Median year housing built	0.020	(0.170)	-0.162	(0.173)
West (1=yes; 0=no)	37.030*	(14.495)	30.147†	(15.571)
Midwest (1=yes; 0=no)	- 16.261†	(9.686)	- 25.836*	(11.008)

Variable	Coef	(Std. err.)	Coef	(Std. err.)
South (1=yes; 0=no)	- 19.758†	(10.401)	- 26.335*	(11.230)
Natural log of supermarket density	-1.197	(2.529)	7.923**	(2.959)
Natural log of natural/health food store density	2.463	(2.900)		
Natural log of fruit/vegetable market density	29.069**	(3.428)		
Natural log of fast food (chain) density	- 6.251**	(1.598)	- 8.274**	(1.825)
Natural log of convenience store density	- 3.726*	(1.825)	-0.629	(1.699)

Variable	Coef	(Std. err.)	Coef	(Std. err.)
Natural log of activity resource density, centered	1.797	(1.392)	4.414**	(1.670)
Crimes reported per 100,000, county level, centered	- 0.004**	(0.001)	- 0.005**	(0.002)
Activity resource density by Crime interaction	0.000	(0.000)	0.000	(0.001)
Intercept	-68.104	(331.142)	291.836	(337.075)
N	6998		6998	
R^2	0.615		0.589	

Variable	Coef	(Std. err.)	Coef	(Std. err.)
F	$F_{(15,114)} = 68.340$		$F_{(13,116)} = 77.957$	

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Note: Numerator and denominator degrees of freedom for the F tests reflect, respectively, regression parameters minus 1 (k), and design degrees of freedom given the sampling frame, minus k. Significance levels: † : 10% * : 5% ** : 1%

In terms of health-related neighborhood contextual factors, most of the signs are as expected. Estimates for fruit/vegetable market density (positive), fast food density (negative), and convenience store density (negative) are significantly different from zero. Thus, neighborhood contextual factors are capitalized. Elasticities are useful in interpreting these coefficient estimates, particularly when both the dependent and independent variables are continuous. Elasticities measure the percentage change in the dependent variable associated with a percentage change in an independent variable. In the first model model, 10 percent rise in the density of fruit and vegetable stores is associated with $2,907 higher home values ($3884 in 2012 dollars). On the other hand, people pay a premium to the avoid convenience stores and fast food chains. A 10 percent rise in the density of fast food chains is associated with $625 lower home values ($824 in 2012 dollars).

Activity resource densities are not significantly related to housing values in the first model. As mentioned, research has shown that in high-crime areas, parks and trails are not valued because they are seen as host sites for criminal activity [12]. Therefore, we examined the interaction between crime rate and activity resource density. However, the interaction term was not significantly related to housing values in the first model.

In order to determine if supermarket density is positively associated with housing values when specialty food stores are not controlled for, the model on the right in Table 2 excludes natural food and fruit and vegetable store densities. Supermarket density is significantly associated with housing values when natural food and fruit and vegetable store densities are excluded. In this model, a 10 percent rise in the density of supermarkets is associated with $792 higher home values ($1,059 in 2012 dollars). Activity density is also significant when natural food and fruit and vegetable store densities are excluded. A 10 percent rise in activity densities is associated with $441 higher home values ($590 in 2012 dollars).

Results by income quartile

Because tastes and preferences for access may differ by income, we also estimated our hedonic regression model separately by income quartile, with results shown in Table 3. Supermarket density is valued amongst block groups in the 1st (lowest) quartile of income when natural food and fruit and vegetable store densities are excluded. A 10 percent increase in supermarket density is associated with $1,128 increased housing values in the 1st quartile ($1,477 in 2012 dollars). People living in neighborhoods in the 1st income quartile in terms of income also value access to fruits and vegetable outlets, paying a hefty premium to have access. A 10 percent increase in fruit and vegetable store density is associated with $2,572 in increased housing values ($3,436 in 2012 dollars).

Table 3

Hedonic regressions predicting median home value, by income quartile

Hedonic regressions for 1st and 2nd income quartiles

	1st Quartile		2nd Quartile	

Hedonic regressions for 1st and 2nd income quartiles

Variable	Coef	(Std. err.)	Coef	(Std. err.)	Coef	(Std. err.)	Coef	(Std. err.)
Natural log of density, block group level	7.558**	(1.330)	9.279**	(1.516)	7.239**	(1.172)	8.144**	(1.240)
Proportion 25+ with a college degree	95.678**	(12.174)	84.024**	(13.238)	81.177**	(16.515)	79.084**	(16.764)
Per capita income, block group level	0.003**	(0.001)	0.003**	(0.001)	0.002†	(0.001)	0.002	(0.001)

Hedonic regressions for 1st and 2nd income quartiles

Median year housing built	0.313*	(0.140)	0.283*	(0.142)	0.5590**	(0.104)	0.462**	(0.115)
West (1=yes; 0=no)	17.376	(11.788)	9.846	(14.623)	12.755	(11.732)	7.506	(15.737)
Midwest (1=yes; 0=no)	-15.118	(13.840)	-25.199	(16.108)	- 22.134†	(12.506)	- 30.016*	(14.680)
South (1=yes; 0=no)	- 22.867*	(11.255)	- 29.218*	(13.670)	- 26.126*	(10.714)	- 31.667*	(13.353)
Natural log of supermarket density	-2.092	(2.796)	11.277**	(2.492)	-3.629	(3.728)	5.812	(3.707)

Hedonic regressions for 1st and 2nd income quartiles

Natural log of natural/health food store density	3.384	(3.421)			7.574*	(3.731)		
Natural log of fruit/vegetable market density	25.715**	(4.653)			21.378**	(4.595)		
Natural log of fast food (chain) density	- 3.613*	(1.783)	- 6.247**	(1.988)	- 3.584*	(1.447)	- 5.139**	(1.539)
Natural log of convenience store density	-2.189	(1.651)	-2.112	(1.565)	-1.215	(1.819)	1.292	(1.820)

Hedonic regressions for 1st and 2nd income quartiles

Natural log of activity resource density, centered	-1.250	(1.241)	0.739	(1.384)	0.264	(1.282)	1.672	(1.306)
Crimes reported per 100,000, county level, centered	- 0.004**	(0.001)	- 0.003**	(0.001)	- 0.004**	(0.001)	- 0.004**	(0.002)
Activity resource density by Crime interaction	0.000	(0.000)	0.001	(0.001)	0.001	(0.000)	0.001**	(0.000)
Intercept	- 614.139*	(278.733)	- 551.610†	(282.031)	- 1076.852**	(207.435)	- 880.393**	(228.512)

Hedonic regressions for 1st and 2nd income quartiles

N	1661	1661	1772	1772
R^2	0.464	0.423	0.425	0.376
F	$F_{(15,113)} = 33.153$	$F_{(13,115)} = 27.518$	$F_{(15,112)} = 15.917$	$F_{(13,114)} = 14.073$

Hedonic regressions for 3rd and 4 th income quartiles

	3rd Quartile				**4th Quartile**			
Variable	**Coef**	**(Std. err.)**	**Coef**	**(Std. err.)**	**Coef**	**(Std. err.)**	**Coef**	**(Std. err.)**

Hedonic regressions for 1st and 2nd income quartiles

Natural log of density, block group level	5.090**	(1.549)	6.132**	(1.899)	13.733**	(4.578)	15.676**	(4.870)
Proportion 25+ with a college degree	80.972**	(17.629)	68.813**	(19.332)	83.874**	(23.607)	66.379**	(24.693)
Per capita income, block group level	0.004**	(0.001)	0.004**	(0.001)	0.006**	(0.001)	0.007**	(0.001)
Median year housing built	0.359*	(0.178)	0.181	(0.193)	-0.395	(0.353)	- 0.621†	(0.333)
West (1=yes; 0=no)	39.481**	(11.579)	32.112*	(13.391)	64.383*	(26.105)	63.959*	(25.560)

Hedonic regressions for 1st and 2nd income quartiles

Midwest (1=yes; 0=no)	-11.640	(9.834)	-20.222†	(11.103)	-8.557	(13.208)	-12.041	(13.671)
South (1=yes; 0=no)	-19.936*	(9.619)	-26.150*	(10.710)	-28.036†	(15.690)	-31.458*	(15.330)
Natural log of supermarket density	-3.867	(3.898)	0.129	(3.264)	9.647	(7.021)	14.727*	(6.887)
Natural log of natural/health food store density	-1.893	(3.549)			1.370	(5.040)		

Hedonic regressions for 1st and 2nd income quartiles

Natural log of fruit/vegetable market density	27.893**	(4.130)			24.695**	(6.120)		
Natural log of fast food (chain) density	- 5.820**	(1.835)	- 7.437**	(2.295)	- 13.022**	(4.590)	- 15.682**	(4.628)
Natural log of convenience store density	-2.628	(1.883)	1.105	(2.032)	- 10.322*	(4.871)	-6.563	(4.236)
Natural log of activity resource density, centered	1.763	(2.041)	4.565†	(2.367)	16.350*	(6.526)	22.061**	(6.921)

Hedonic regressions for 1st and 2nd income quartiles

Crimes reported per 100,000, county level, centered	- 0.004**	(0.001)	- 0.005**	(0.001)	- 0.008*	(0.003)	- 0.009*	(0.003)
Activity resource density by Crime interaction	0.000	(0.001)	0.001	(0.001)	0.001	(0.002)	0.000	(0.002)
Intercept	-703.002†	(357.401)	-350.978	(386.007)	684.759	(687.906)	1120.822†	(651.149)
N	1802		1802		1763		1763	
R^2	0.419		0.357		0.520		0.507	

Hedonic regressions for 1st and 2nd income quartiles

F	$F_{(15,111)} = 14.956$	$F_{(13,113)} = 8.26$	$F_{(15,109)} = 21.092$	$F_{(13,111)} = 25.89$

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Note: Numerator and denominator degrees of freedom for the F tests reflect, respectively, regression parameters minus 1 (k), and design degrees of freedom given the sampling frame, minus k. Significance levels: †: 10% *: 5% **: 1%

People living in neighborhoods in the 1st and 2nd quartiles of income are willing to pay a small premium to avoid fast food outlets. Results from the first model for quartile two show that a 10 percent increase in access to fast food restaurants (density) is associated with housing values that are $358 lower ($479 in 2012 dollars).

Although people pay a premium to avoid crime in neighborhoods in the 1st and 2nd quartiles of income, they are not willing to pay a premium for access to PA resources. As noted earlier, this may be due to the fact that in low-income areas, parks are perceived as places for criminal activity [12].

The lower half of Table 3 shows the results for census blocks with incomes in the 3rd and 4th quartiles, revealing some differences in comparison to the estimates in the upper half of Table 3. Supermarket density is associated with housing price for the 4th quartile of income when natural food and fruit and vegetable store densities are excluded. A 10 percent increase in supermarket density is associated with $1,473 ($1,966 in 2012 dollars). In the 3rd quartile, a 10 percent increase in fruit and vegetable store density is associated with $2,789 higher housing costs ($3,727 in 2012 dollars).

The premium for avoiding convenience stores is inconsistent across neighborhoods by income quartile, but there is a premium to avoid fast food in all models. For instance, in the first specification of the 4th quartile model, a 10 percent increase in access to fast food is associated with $1,302 in lower housing values ($1,740 in 2012 dollars).

Finally, wealthier neighborhoods also pay a higher premium for access to PA resources. In the full model for the 4th quartile, housing values are $1,635 higher ($2,184 in 2012 dollars) when activity resource density increases by 10 percent.

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Discussion

That the price of nearly identical dwellings in different neighborhoods can differ so dramatically reveals disparities in locational attributes. Our analysis reveals that physical attributes related to health are capitalized into higher housing values, *i.e.*, it costs more to live in those areas. Because the hedonic price model is essentially a bid model, capitalization can be thought of as evidence of preference, at the aggregate level, for a given neighborhood and its attributes versus alternative neighborhoods.

We found that access to fruit and vegetable stores are highly capitalized. For instance, a 10 percent rise in the density of fruit and vegetable stores, which could be one store opening, is associated with $2,907 higher home values ($3,884 in 2012 dollars). This result was consistent across neighborhoods with different income levels. Supermarket access was capitalized when variables for the densities of fruit and vegetable and natural food stores were excluded. However, fruit and vegetable store access always dominated supermarket access overall and across neighborhoods with different income levels.

In some cases, attributes which are detrimental to health are negatively capitalized, meaning housing values are discounted in those areas. In our study, people valued the avoidance of convenience stores and fast food chains. We found that a 10 percent rise in the density of fast food chains is associated with $625 lower home values ($884 in 2012 dollars).

We also found that capitalization varied by neighborhood income levels. Wealthier neighborhoods pay a higher premium for access to PA resources. Among neighborhoods in the 4th quartile, housing values are $1,635 higher ($2,184 in 2012 dollars) when activity resource density increases by 10 percent. Although people valued PA resources overall, activity resources are not consistently valued, especially among those with lower income. This implies that projects to improve access to parks and trails in a poor area may lead to wealthier people bidding up the value of nearby houses and apartments.

All neighborhood types paid a premium to avoid fast food, but the distaste premium increased by neighborhood income level. A 10 percent increase in access to fast food is associated with $1,302 ($1,740 in 2012 dollars) in lower housing values among

neighborhoods in the 4th income quartile. The distaste premium for convenience store access also increased by neighborhood income level.

Our results suggest that differential spatial access to health-related amenities is associated with capitalization. Capitalization has equity concerns in a bid model because wealthier persons will inevitably be able to outbid lower income people. Policies should encourage ubiquitous access to healthy food and PA opportunities, because without differential access, capitalization will not occur. Some policies exist to spread access, such as enterprise zones offering advantageous tax policies for supermarkets. Our results show that access to small fruit and vegetable markets are *more* valued than supermarkets, so subsidies to convenience stores, which themselves have negative valuation, to sell healthier foods would help equalize access. In terms of PA, smaller parks in several locations would be preferred to a single large park (or a few large parks). This is because access to a single large park is easier to capitalize.

While capitalization has equity concerns, our results offer a heretofore unavailed of method to reveal the value persons place on access to health-related amenities. The preference for access, particularly access for healthy food, extends to neighborhoods of all income levels.

Our hope is that in future research efforts, we will be able to use capitalization to control for selection, revealing the true health effects of the built environment.

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Limitations

One critical caveat to our findings is that they are relational, but not necessarily causal. For instance, an increase in the health-related amenities near a location can result in increased prices because the amenities make the location of the property more valuable. Even announced or prospective changes in an area's amenities can affect housing pricing far before these additional amenities exist. For example, houses in a neighborhood may increase in value at the announcement of potential plans for building a neighborhood park, since this reflects the interest of developers in the area's growth and improvement. Both are examples of increased amenities, actual or planned, driving housing prices.

However, directionality may also work in the opposite direction. For instance, in the scenario of owned condominiums or gated communities, the building of a new walking or exercise area may depend on whether there has been an increase in the buying value of these homes. The additional income generated by the upscaled prices may be part of a development plan for the condominium or gated community to improve the value of the group of homes, which will in turn, increase prices even further. Thus, it is likely that in some scenarios, amenities and prices affect each other reciprocally. Our data were from a single wave, but future research considering multiple waves of data on amenities and home prices may help distinguish directions of causality.

Additionally, our data reflect a particular historical period in the U.S. housing market, the early 2000s, which we chose because of the relative absence of bubbles and busts [32].

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Conclusions

In this study, we addressed a gap in the literature by linking research on the contextual factors that facilitate or impede a healthy lifestyle with the hedonic price framework, allowing us to estimate the degree to which these factors are capitalized into housing prices. Although the non-randomness of location is generally acknowledged in the health economics literature, our results highlight the extent and magnitude of the non-randomness. Our results show that, even among people in the lowest income quartile, access to better food comes at a premium. It is acknowledged that income and health are highly correlated, and our results show that the health benefits of better access to food among the poor comes at the cost of reduced income, net of housing costs. This perhaps explains the mixed results in the literature.

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Endnotes

[1] Note, however, that there can also be high-income neighborhoods away from the city, since some prefer to build larger houses on several acres. However, buying the same house on the same number of acres, holding crime, schools, etc., constant, closer to the center of the city would cost more. For example, Victorian homes in Manhattan were eventually sold due to the increasing importance of New York City.

[2] Note that the Tiebout model is more concerned with efficient taxation than capitalization [10].

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Competing interests

Both authors declare that they have no competing interests.

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Authors' contributions

HSB conceived of the study and analytic methods, and participated in reviewing results. LMY carried out the analyses and conceived of adjustments to models. Both authors contributed to the writing of this manuscript, and approve the final manuscript.

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Fast Food Crime Prevention

"You Want Fries with that Knuckle Sandwich"?

Fast Food Crime is on the Rise.
Security Expert J. R. Roberts explains why.

¨ **An elderly patron** sitting quietly at a table outside a popular fast food hamburger chain is suddenly and viciously attacked. His assailant (an employee who has just had an argument with his manager) uses the lid of a trash can to repeatedly beat the old gentleman on the head. He then uses a garbage bag in an effort to suffocate him.

¨ **A young assistant manager** of a chicken chain is closing up the restaurant for the evening when he is confronted by two armed robbers who shoot and kill him.

¨ **A patron** sitting in a fast food drive through window is taken by surprise when the occupants of the car in front of him, leap from their vehicle and beat and rob him.

¨ **An employee** of a pizza chain opens the back door to find masked men with shotguns waiting. They rob the store, order the employees to the ground and shoot them as they exit.

All across the United States scenes like these are repeated with frightening frequency. The fast food industry currently employs 12 million Americans in 878,000 establishments. Projected earnings for 2004 are expected to reach 440.1 billion dollars.

A parallel between fast food chains and convenience stores is obvious. Often referred to as "stop and robs" the convenience store industry continues to be an exceedingly "high risk" target for criminal opportunity. Recent changes and growth in the fast food industry, however, are placing that business at an increasingly higher risk.

Location

Most fast food chains are located along major corridors and freeways, making access quick, easy and low risk to the perpetrator who can make a quick score.

Higher rates of speed and choice of multiple directions for escape further compound the problem.

Corporations very often target specific demographics that equal high traffic and potential profit, while failing to properly prepare for the increased crime that invariably accompanies such site selections. At the same time, most if not all fast food chains have begun a "late night" policy of extended hours of operation.

Environment

Like bank ATM's, many fast food facilities are often inadequately designed from a safety and security standpoint.

Poorly designed and overgrown landscaping, inadequate lighting, "blind spots" at the drive through lane and throughout the parking lot combined with pill box or bunker designs reduce or eliminate critical "natural territoriality" (the crucial ability to see and be seen.)

These same lots are often poorly maintained, allowing litter and even graffiti to take root.

These poor "order maintenance" issues send a cue to the would be perpetrator that the facility will be a quick and easy target with fewer chances of being observed, detected, or deterred.

Few of these locations properly utilize, place, or monitor CCTV components, or provide multiple location panic buttons or alarms.

Policies & Procedures

There is an almost universal failure on the part of owners and operators of fast food restaurants to properly screen employees. Criminal background/felony conviction reviews are inexpensive to conduct and should be considered mandatory when it comes to the consideration and concern of the safety and security of fellow employees and patrons.

Opening and closing procedures should be carefully considered, reviewed, and enforced by management.

Thorough training should include regular cash "drops" into a safe and signage should make clear that employees can not open safe.

Signs that announce limited cash available, height markers, and visible use of CCTV for the interior of a store, should all be considered standard.

Bullet resistant glazing should be used on all teller/drive through windows.

Robbery training and response should be instructed to all employees. Stores open late should be open for drive through only, and managers and employees closing late should have security presence/escort until they are safely off the property.

Local police departments invariably provide at no cost an analysis or "threat assessment" of a facility together with security suggestions. Such an analysis can also include a review of crime in the general area. A search of crime within the "zone" or "grid" where a commercial establishment is located can reveal much concerning the likelihood of criminal activity.

Conscientious and responsible owners determined to reduce crime and civil liability resulting from allegations of negligent and inadequate security should undertake a serious review of their premises unless they want a "side" of trouble.

By J. R. Roberts

https://crimeschool.com/fast-food-security-violent-crime/

Fast Food Security – Violent Crime at Quick Service Restaurants

July 3, 2017 Chris McGoey

Fast Food Security is Necessary at Some Quick Service Restaurants

- Crime risk factors: Urban location, quick access, and late night hours
- Prior crime history and nature of the premises will determine crime risk

http://journals.sagepub.com/doi/abs/10.1177/0011128717714792

Fast Food Restaurants and Convenience Stores: Using Sales Volume to Explain Crime Patterns in Seattle

Show all authors
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Abstract

This study investigates how convenience stores and fast food restaurants influence crime patterns over time. Using sales volume data from fast food restaurants and convenience stores, we examine streetblock crime levels over a seven year period in Seattle using multilevel models. Results demonstrate that high sales volume links to high crime, even after controlling for local socio-economic status, the effects of retail businesses, and local crime trends. In addition, street segment crime trajectories were spatially clustered in a significant way. The dynamics that explain why specific types of commercial facilities link to street crime need further theoretical clarification. This is the first study demonstrating significant spatio-temporal patterning of streetblock crime trends.

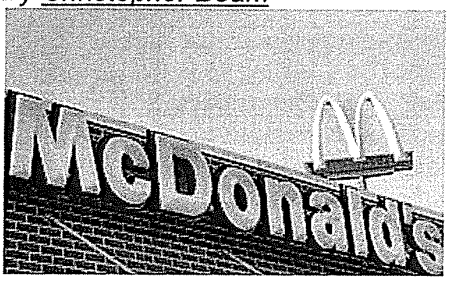
HTTP://WWW.SLATE.COM/ARTICLES/NEWS_AND_POLITICS/CRIME/2011/04/MCRAGE.HTML

MURDER, THEFT, AND OTHER WICKEDNESS.
APRIL 27 2011 7:46 PM

McRage

Why is there so much violent crime at fast-food restaurants?

By Christopher Beam



Does danger wait beneath the golden arches?

When video of the **brutal assault** of a transgendered woman at a McDonald's near Baltimore went viral last week, McDonald's released a **statement**: "There's no room for violence under the Golden Arches." But in the annals of American crime, the fast-food-chain assault has become as iconic as the postal-worker shooting spree.

In January, Toledo, Ohio, resident Melodi Dushane **punched out** a McDonald's drive-through window when she was told they didn't sell Chicken McNuggets in the morning. Another woman recently **drove through** a crowd of people in a McDonald's parking lot, **injuring four**. In 2008, a Los Angeles man **punched** a 16-year-old girl in the face at a McDonald's after she complained about him cutting the line. A Wendy's customer reportedly **assaulted** a female clerk at a drive-through window in 2007 after she didn't tell him to "have a nice day." The **list goes** on. Spike Jonze even made a fast-food beating the centerpiece of his **music video** for Arcade Fire's "The Suburbs." (You can find a compilation of restaurant violence **here**.)

Fast-food restaurants haven't entirely replaced banks as crime targets, and criminal activity in such places is no longer **on the rise**. (**Crimes like this**, however, are.) The Bureau of Labor Statistics estimates that the number of homicides at "**limited service restaurants**," which include fast-food chains like McDonald's and KFC, has declined from 35 in 2007 to 15 in 2009. But fast-food establishments like Wendy's and Burger King do see more crime than their "full-service" counterparts, like Ruby Tuesday's or the Olive Garden. BLS estimates that the rate of assaults at limited-service restaurants is more than twice as high as at full-service restaurants. Whereas sit-down restaurants had 0.8 assaults per 10,000 employees in 2009, fast-food joints had 1.8.

Why the difference? The primary reason is that fast-food chains are unusually vulnerable to robbery, which accounts for most of the violence at fast-food stores. Like gas stations and

convenience stores, fast-food chains open early and close late. But customers there tend to use cash more than at gas stations, which have switched almost entirely to credit cards. And unlike convenience stores, fast-food places don't always limit the amount of cash that an employee can access. It doesn't help that fast-food workers are paid so little. More often than not, the robber is a friend of an employee or an **employee himself**. Location is a factor, too. What makes McDonald's restaurants so convenient to customers—they're located at major thoroughfares and intersections—also makes them great robbery targets. (Drive-throughs make for especially easy getaways.)

Demographics play a role as well. McDonald's **bourgie makeover**notwithstanding, most fast-food chains cater largely to young, low-income customers. (Burger King's since-abandoned "The King" campaign was specifically aimed at "**young adult male consumers**.") Restaurants in high-crime areas will occasionally become crime scenes. Fast-food chains become easy places to loiter, which can lead to arguments or worse. "When you've got a relatively uneducated, young workforce and piss-poor management, put them in a high-stress situation—a burger-and-fries environment—and you'll get some improper conduct," says David Van Fleet, a professor of management at Arizona State University and co-author of ***The Violence Volcano: Reducing the Threat of Workplace Violence***.

Customers may feel stressed out, too. Professors at the University of Toronto **released a study** in 2010 concluding that exposure to the logos of fast-food chains like Wendy's and Burger King made people hasty and impatient. When "fast" food doesn't live up to its name, people might lash out.

The "**trend**" of fast-food violence isn't really a trend. Any apparent uptick in domestic abuse at the Home of the Whopper probably owes more to YouTube and camera phones than to growing unruliness. But as with postal workers, all it takes are **a few bad apples**. Goodbye "going postal"; hello "McRage."

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Aesthetic Zoning: Property Values and the Judicial Decision Process

Sheldon Elliot Steinbacht

AESTHETIC ZONING: PROPERTY VALUES AND THE JUDICIAL DECISION PROCESS

SHELDON ELLIOT STEINBACH*

*Beauty may not be queen but she is not an outcast beyond the pale of protection or respect. She may at least shelter herself under the wing of safety, morality or decency.***

"[W]hile public health, safety, and morals, which make for the public welfare, submit to reasonable definition and delimitations, the realm of the aesthetic varies with the wide variation of tastes and culture."[1] Encompassed within the term "general welfare" is the concept of economic well-being and spiritual comfort and to some minds, "[t]he most important facet of spiritual comfort is aesthetic zoning."[2]

Exponents claim that the principle purpose of aesthetic zoning is to enhance or preserve the physical appearance of the community by eliminating or reducing dissimilarity, monotony, and incongruity in the physical appearance of structures within the neighborhood. Put more simply it is the goal of aesthetic zoning ". . . to promote, preserve or restore beauty, and to remove or hide eyesores."[3] The courts have played a major role in the development of aesthetic concepts in zoning but have also constituted one of the major roadblocks to the complete acceptance of aesthetics *per se* as a valid basis for zoning.

> Traditionally the opinions have refused to face up to the aesthetic questions posed by the cases. It is clear enough in the great majority of zoning decisions that one of the predominating purposes of zoning legislation is the maintenance and improvement of community appearance. But traditionally the courts have exercised remarkable powers of imagination to find legislative concern limited to matters of light, air, traffic control and sewage disposal even where the aesthetic impact of the decision is obvious.[4]

Thus, when an aesthetic consideration has been raised, it generally has been upheld if it could be fitted into one of the traditional molds that en-

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**This statement was made by the New York Court of Appeals in Perlmutter v. Greene, 259 N.Y. 327, 332, 182 N.E. 5, 6 (1932).

1. Norris v. Bradford, 204 Tenn. 319, 324, 321 S.W.2d 543, 545 (1958) (city zoning ordinance prohibiting front yard fences in residential districts).

2. Note, *Aesthetic Zoning: A Current Evaluation of the Law,* 18 U. FLA. L. REV. 430, 433 (1965).

3. *Id.*

4. Comment, *Aesthetic Control of Land Use: A House Built Upon the Sand,* 59 NW. U.L. REV. 372, 373 (1964).

compass public health, safety, morals, or general welfare. Once the concession has been made to allow city councils to consider aesthetics, one finds that the ordinance is upheld only if it can be sustained in its entirety upon a non-aesthetic ground.[5]

The reluctance of courts, as well as certain segments of the public, to accept aesthetics as the sole basis for zoning stems from a reverence for the historic rights of private property. Put in the least favorable light, aesthetic zoning may be considered as the exercise of the police power to restrain an individual in the use of his private property so that the community may have the luxury of gazing upon pleasant surroundings. Many feel that the property owner should not be compelled to bear the financial burden of making the community beautiful but instead that the community itself should pay for preserving the beauty of the community.[6] In addition, judges and laymen alike look with disfavor upon the uncertainty caused by the use of aesthetic standards in drafting legislation.[7] Certainly it is not an idle fear that the lack of precise standards may lead to discriminatory enforcement. For these reasons courts have moved slowly in the area of aesthetic zoning, trying to delicately balance the rights of private property against an ill-defined desire of the citizenry to have a more beautiful community to live in.

I. Aesthetic Basis for Regulation

A. *Development of the Concept*

Although the law reviews and journals have been filled with material on the topic of aesthetic zoning, only a few states have *fully* embraced aesthetics as a singular basis for land regulation. Most states have either recognized aesthetics by aligning it with an expansion of the traditional notion of public welfare, or they have rejected it outright.

The first major case to uphold a comprehensive zoning plan was *Euclid v. Ambler Realty Co.*[8] decided by the Supreme Court of the United States in 1926. Since that decision, there has been little doubt that the police power could constitutionally be utilized to restrain an individual's use of his property in the furtherance of the public welfare. However, the Supreme Court failed to define the concept of "general welfare."[9] The significance of *Euclid* was the introduction into zoning considerations of the concept of "utilitarianism" which balances individual interests against

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5. *See* Jackson v. Bridges, 243 Miss. 646, 139 So. 2d 660 (1962). The word aesthetics has a bad aroma in some courts. Negative attitudes are discussed in Anderson, *Architectural Controls,* 12 Syracuse L. Rev. 26, 32-33 (1960).

6. Comment, *Aesthetics as a Zoning Consideration,* 13 Hast. L.J. 374, 378 (1962).

7. Comment, *Aesthetic Considerations and the Police Power,* 35 B.U.L. Rev. 615 (1955).

8. 272 U.S. 365 (1926).

9. *Id.* at 387.

the general welfare of the community. The court pointed out that zoning ordinances benefited the entire community and could not possibly operate without some prohibition being placed on the utilization of property.[10]

The road of aesthetic zoning has been a hazardous one beset with obstructions and detours. The earliest decisions in the area of aesthetic zoning are typified by *Passaic v. Paterson Bill Posting, Advertising & Sign Painting Co.*[11] There the court held that aesthetic considerations were a matter of luxury and indulgence rather than necessity, and therefore it was necessity alone which justified the utilization of police power to regulate private property without compensation.[12]

Although progress had been made in some areas (*e.g.*, billboards and historic structures), the first real break-through for aesthetics came with the 1954 case of *Berman v. Parker*.[13] The Supreme Court of the United States included aesthetics as a permissible basis for the condemnation of private property under the District of Columbia Redevelopment Act of 1945. The court held that even though the appellant's property was neither slum nor blighted, the police power could be invoked to appropriate the land and develop a more attractive community. Mr. Justice Douglas, writing for a unanimous court stated:

> The concept of public welfare is broad and inclusive. . . . [t]he values it represents are spiritual as well as physical, aesthetic as well as monetary. It is within the power of the legislature to determine that the community should be beautiful as well as healthy, spacious as well as clean . . . . If those who govern the District of Columbia decide that the Nation's Capital should be beautiful as well as sanitary, there is nothing in the Fifth Amendment that stands in the way.[14]

It should be pointed out that there are differences between *Berman* and cases arising at the state level. *Berman* arose under federal jurisdiction and dealt with the power of eminent domain, whereas most state courts deal with the right to zone under the police power. State courts test police power legislation more strictly under the fourteenth amendment than the Supreme Court tests the right of eminent domain under the fifth amendment even though all courts weigh these powers against due process considerations.[15] Finally, even though the decisions of the Supreme Court on federal questions are not controlling in state courts, they are

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10. *Id.* at 389.
11. 72 N.J.L. 285, 62 A. 267 (Ct. Err. & App. 1905).
12. *Id.* at 287, 62 A. at 268. However property rights as protected under the due process clause constitute an ever shifting, counting, and balancing of conflicting societal interests. Pound, *A Survey of Social Interests,* 57 HARV. L. REV. 1 (1943).
13. 348 U.S. 26 (1954).
14. *Id.* at 33.
15. Comment, *Zoning, Aesthetics, and the First Amendment,* 64 COLUM. L. REV. 81, 85 (1964).

highly persuasive when the latter are considering the interpretation of their own constitutions.[16]

The first major state court decision after *Berman* was the Wisconsin case of *State ex rel. Saveland Park Holding Corp. v. Wieland*[17] which was based upon both aesthetics and the protection of property values. The ordinance required that in order for a building permit to be issued, the city's zoning board had to find that the exterior architectural appeal and functional plan of the proposed building would not cause a substantial diminution of property values within the neighborhood.[18] The court felt that the preservation of property values was a legitimate ground for the exercise of the police power. The judgment was based on the conviction that anything that destroys property values ultimately affects the prosperity and general welfare of the community.

Another assault upon the barriers to aesthetic zoning culminated in victory in the New York case of *People v. Stover*[19] where, for the first time, a state court upheld a zoning ordinance based solely upon aesthetic grounds. The case concerned a violation of an ordinance prohibiting the maintenance of clotheslines in a front or side yard. The defendant had erected clotheslines and decorated them with dirty laundry in order to protest high municipal taxes. The court held that the ordinance

> may be sustained as an attempt to preserve the residential appearance of the city and its property values . . . . [T]he statute, though based on what may be termed aesthetic considerations, proscribes conduct which offends sensabilities and tends to debase the community and reduce real estate values.[20]

The court conceded that aesthetics is a valid subject of legislative concern and that reasonable legislation designed to implement this end is a permissible exercise of the police power. However, the court did intimate that situations may arise where "the legislative body goes too far in the name of aesthetics . . . but the present, quite clearly, is not one of them."[21]

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16. Agnor, *Beauty Begins a Comeback: Aesthetic Considerations in Zoning*, 11 J. PUB. L. 260, 278 (1962). Some courts that recognize the differences between jurisdiction based on the power of eminent domain and the police power to zone have little difficulty reaching a reconciliation. *See* Oregon City v. Hartke, 240 Ore. 35, 44, 400 P.2d 255, 261-62 (1965) and Phoenix v. Fehlner, 90 Ariz. 13, 17, 363 P.2d 607, 609-10 (1961).

17. 269 Wis. 262, 69 N.W.2d 217 (1955), *cert. denied*, 350 U.S. 841 (1955). *See generally* Sayre, *Aesthetics and Property Values: Does Zoning Promote the Public Welfare*, 35 A.B.A.J. 471 (1949).

18. State *ex rel.* Saveland Park Holding Corp. v. Wieland, 269 Wis. 262, 265, 69 N.W.2d 217, 219; *See also* Deering *ex rel.* Bittenbender v. Tibletts, 105 N.H. 481, 202 A.2d 232 (1964). In State *ex rel.* American Oil Co. v. Bessent, 27 Wis. 2d 537, 135 N.W.2d 317 (1956), the court relying on *Saveland* and *Berman* held that a comprehensive village zoning ordinance was valid. In so holding, the court accepted the proposition that the concept of public welfare includes within comprehensive zoning the borderlines of community growth, land value, and aesthetic objectives.

19. 12 N.Y.2d 462, 191 N.E.2d 272, 240 N.Y.S.2d 734 (1963).

20. *Id.* at 466, 191 N.E.2d at 274, 240 N.Y.S.2d at 737.

21. *Id.* at 468, 191 N.E.2d at 275, 240 N.Y.S.2d at 739.

The trend continued in 1965 when an Oregon court stated that it concurred with the New York view "that aesthetic considerations alone may warrant an exercise of the police power."[22] The case involved an ordinance that totally excluded wrecking yards from the city limits and was upheld though exclusively based on aesthetic considerations. The court stated that

> there is a growing judicial recognition of the power of a city to impose zoning restrictions which can be justified solely upon the ground that they will tend to prevent or minimize discordant and unsightly surroundings. This change in attitude is a reflection of the refinement of our tastes and the growing appreciation of cultural values in a maturing society. The change may be ascribed more directly to the judicial expansion of the police power to include within the concept of "general welfare" the enhancement of the citizen's cultural life.[23]

In *Cromwell v. Ferrier*,[24] an individual's business, consisting of a service station and diner, was bisected by a highway so that his advertising sign was situated on the side of the highway opposite his business, thereby making his sign nonaccessory. The comprehensive zoning ordinance prohibited nonaccessory signs anywhere in the township. The court sustained the ordinance and stated that a zoning ordinance "is not necessarily invalid because its primary, if not its exclusive objective, is the aesthetic enhancement of the particular area involved, so long as it is related if only generally to the economic and cultural setting of the regulating community."[25]

B. *Specialized Areas of Regulation*

1. Billboards

One of the areas in which aesthetic desiderata of a specialized nature have made great progress is that of billboard regulation.[26] In 1936, the Massachusetts Supreme Court, speaking in a case involving billboard regulation, stated:

> [g]randeur and beauty of scenery contribute highly important factors to the public welfare of a state. To preserve such landscape from defacement promotes the public welfare and is a public purpose. . . . Even if the rules and regulations of billboards . . . did not rest upon the safety of public travel and the promotion of the comfort of travelers by exclusion of undesired intrusion,

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22. Oregon City v. Hartke, 240 Ore. 35, 49, 400 P.2d 255, 262 (1965).
23. *Id.* at 46, 400 P.2d at 261.
24. 19 N.Y.2d 263, 225 N.E.2d 749, 279 N.Y.S.2d 22 (1967).
25. *Id.* at 269, 225 N.E.2d at 753, 279 N.Y.S.2d at 26.
26. In the federal interstate highway program Congress has made provision for control of outdoor advertising through the 1965 Federal Highway Beautification Act, 23 U.S.C. § 131 (1965).

> we think that the preservation of scenic beauty and places of historic interest would be sufficient support for them.[27]

This statement reflects the attitude of those courts which have deemed aesthetics to be an independent basis for legislation in the area of billboard regulation. The general feeling of these courts has been that the legislatures in enacting billboard legislation may not only give consideration to promoting public safety but can legally consider the comfort, convenience, and peace of mind of those using the highways.[28]

Illustrative of this feeling is the Hawaii Supreme Court's most recent decision in *State v. Diamond Motors*,[29] where defendants were convicted of violating an ordinance which limited the size and height of outdoor signs in an industrial area. The court held that the application of the ordinance to signs in industrial areas constituted a regulation for public welfare, and even if its primary purpose was an aesthetic one, it was a valid exercise of the police power and did not constitute a taking of property without compensation. The court even chided the city for not supporting the proposition that aesthetics alone is a proper objective for the exercise of police power.[30]

2. Preservation of Historic Structures

The preservation of historic buildings has also evoked much interest in recent years both for aesthetic and economic reasons.[31] For example, an

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27. General Outdoor Advertising Co. v. Dep't of Public Works, 289 Mass. 149, 183, 193 N.E. 799, 816 (1935). For a compendium of cases involving the power of municipalities as to billboards and other outdoor advertising see Annot., 72 A.L.R. 465 (1931) and Annot., 58 A.L.R.2d 1314 (1958).

28. *E.g.*, Markham Adv. Co. v. State, 439 P.2d 248, 260 (1968), summarizing the full impact of aesthetics on billboard regulation; State v. Diamond Motors, 429 P.2d 825 (Hawaii 1967); Cromwell v. Ferrier, 19 N.Y.2d 263, 225 N.E.2d 749, 279 N.Y.S.2d 22 (1967); Ghaster Properties, Inc. v. Preston, 176 Ohio St. 425, 200 N.E.2d 328 (1964); Dessert Outdoor Adv. v. San Bernadino, 255 Cal. App. 469, 63 Cal. Rptr. 543 (1967), including a comprehensive combination of all aspects of aesthetics. *See also* New York State Thruway Authority v. Ashley Motor Court, Inc., 10 N.Y.2d 151, 176 N.E.2d 566, 218 N.Y.S.2d 640 (1961).

In *Cromwell*, a divided court found that the unique nature of billboard advertising has long made it a separate category for governmental regulation. The court found it unnecessary to discuss the blight caused by the massive erection of billboards but noted that their harmful effects upon driver safety have substantially increased and that an increasing number of states are regulating billboard advertising. In summarizing the law in this area the court concluded that the "eye is entitled to as much recognition as the other senses . . ." and that when misplaced, billboards were "egregious examples of ugliness, distraction and deterioration." Cromwell v. Ferrier, *supra* at 272, 225 N.E.2d at 755, 279 N.Y.S.2d at 30. The dissent felt that the ruling constituted a serious interference with a man's right to use his own property.

29. 429 P.2d 825 (Hawaii 1967).

30. *Id.* at 827, citing Dukeminer, *Zoning for Aesthetic Objectives: A Reappraisal*, 20 LAW & CONTEMP. PROB. 218, 237 (1955).

31. *See, e.g.*, Neef v. Springfield, 380 Ill. 275, 43 N.E.2d (1942), where a city zoning ordinance prohibiting the use of property for gasoline service stations in cer-

Historic Districts Commission has been established in Massachusetts "to pass upon the appropriateness of exterior architectural features of buildings and structures wherever such exterior features are subject to public view from a public street or way."[32] The resultant legislation was directed towards the preservation of the Beacon Hill section of Boston, Lexington, Falmouth, Salem, and Concord. The legislation was held constitutional in an advisory opinion by the Supreme Judicial Court. The opinion stated that failure to regulate the erection of buildings would result in destruction of one of the town's principal assets.[33] Similar legislation was also enacted by the city of New Orleans in 1937 to protect its picturesque Vieux Carre section. The ordinance specifically stated that its purpose was to protect the "quaint and distinctive character" of the area.[34]

Several state court decisions have recognized the importance of preserving historic structures.[35] Preservation of a historic style of architecture was the issue in *Sante Fe v. Gamble Skogmo, Inc.*[36] where the defendant corporation was found guilty of violating the city's building code. The New Mexico Supreme Court held that regulation of the size of building windows within an historic area of Santa Fe as a means of preserving the "Old Sante Fe Style" of architecture was a valid exercise of the police power since the "general welfare" of the community was enhanced through any income derived from tourist trade attracted by this area of the city.[37]

3. Tourism

In some states, where tourism is a major source of revenue (as in the *Gamble Skogmo* case noted above), courts have tied together tourism, aesthetics, and the preservation of property values in developing a rationale for upholding zoning laws. The cases indicate that where certain portions of the state have high tourist traffic, there is an assumption that the tourist industry is enhanced by the aesthetic appeal of the area.[38] However, this

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tain kinds of residential districts was held to be a valid exercise of police power even though it was assumed that a major factor in the enactment of the regulation was the interest of city officials in the preservation of the beauty of the area near Abraham Lincoln's tomb.

32. MASS. GEN. LAWS ch. 601, §§ 4, 5, 8 (1955).

33. Opinion of the Justices, 333 Mass. 773, 780, 128 N.E.2d 557, 562 (1955).

34. NEW ORLEANS, LA. VIEUX CARRE ORD. No: 14 538 C.C.S. § 3 (1937). *See also* New Orleans v. Levy, 223 La. 14, 64 So. 2d 798 (1953), where an ordinance providing for the preservation of the quaint and distinctive character of the area was upheld.

35. *E.g.* Derring *ex rel.* Bittenlender v. Tibbetts, 105 N.H. 481, 202 A.2d 232 (1964), where the court held that the aesthetic considerations of fostering civic beauty and preserving places of historic and architectural merit were enough to support the valid exercise of the municipality's police power.

36. 73 N.M. 410, 389 P.2d 13 (1964).

37. *Id.* at 418, 289 P.2d at 18 (emphasis added).

38. *See* Opinion of the Justices, 103 N.H. 268, 169 A.2d 762 (1961): "We hold that the maintenance of the natural beauty of areas along interstate highways is to be taken into account in determining whether the police power is properly exer-

concept has not yet gained wide recognition. Since most states do have some tourist trade, there is always a possibility that the courts can be persuaded to permit aesthetic zoning for the combined purposes of beauty and economics.

C. *Present Trends*

As the above discussion indicates, while aesthetics has been a factor in governmental regulation, its outright acceptance by the courts as the sole basis for zoning has been limited.[39] However, there are forces at work within our society that have tended to elevate the American taste. Among these influential elements are: rising real income; increasing education, both formal and informal; the success of the so-called "tastemakers" in spreading their ideas; and the American ethic of striving for self betterment.[40]

The present trend appears to be toward the close association of aesthetics and property values. For example, in a 1964 New Jersey case, the court stated:

> [T]here are some areas in which aesthetics and economics coalesce, areas in which a discordant sight is as hard an economic fact as an annoying odor or sound. We refer not to some sensitive or exquisite preference but to concepts of congruity held so widely that they are inseparable from the enjoyment and hence the value of property.[41]

The health and safety of the community has been the predominant justification behind the imposition of set-back controls[42] and the sanctioning of minimum lot size requirements.[43] Courts have found the traditional label of health easier to apply than the newer concept of aesthetics. However, in recent years courts have acknowledged a dual basis for their

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cised." *See also,* Miami Beach v. Ocean & Inland Co., 147 Fla. 480, 3 So. 2d 384 (1941), where the court stated, "It is difficult to see how the success of Miami Beach could continue if its aesthetic appeal were ignored because the beauty of the community is a distinct lure to winter travelers."

39. A 1965 note in the FLORIDA LAW REVIEW indicated that only New York, Oregon and the District of Columbia have accepted aesthetics as a basis for zoning and that the following eighteen states have rejected aesthetics as a *sole* basis for zoning: Cal., Del., Ill., Iowa, La., Md., Mich., Minn., Miss., Mo., Neb., Nev., New Mexico, N.C., Ohio, Tenn., Tex., Wash., and W.Va. Note, *Aesthetic Zoning: A Current Evaluation of the Law,* U. FLA. L. REV. 430, 437-38 (1965).

40. Burch, *How American Taste is Changing,* FORTUNE, July, 1959, at 115.

41. United Adv. Corp. v. Metuchen, 43 N.J. 1, 5, 198 A.2d 447, 449 (1964). This presents a perfect example of the confusion existing in most courts when the issues of pure aesthetic concepts and economic depreciation are both raised.

42. Gorieb v. Fox, 274 U.S. 603 (1927). For a complete discussion of the validity of front setback provisions within zoning ordinances see Annot., 93 A.L.R.2d 1223 (1964).

43. Simon v. Needham, 311 Mass. 560, 42 N.E.2d 516 (1942). *See also* Annot., 96 A.L.R.2d 1367 (1964).

decisions. A 1952 New Jersey case focused considerable attention on aesthetic principles while simultaneously looking at the relationship between health and adequate living space.[44]

While the reluctance to adopt aesthetics as the exclusive basis for zoning (regardless of the affect on property values) will be with us for a long time, the use of the concept of "police power" to uphold zoning laws is gaining momentum and might aid in decreasing the time necessary for full acceptance of aesthetic zoning. "Police power" has been recognized as an expanding legal device that is as comprehensive as the demands of society dictate, and evolves with the changing concepts of what constitutes the "public welfare."[45] The concept of aesthetics in zoning may well be accepted under a broadened definition of "general welfare" without being recognized officially as being the implementation of aesthetics.

II. Future Problems and Alternatives

Future considerations in the area of aesthetics and zoning necessitate a review of the associated problems and alternative solutions involved. Initially, it seems necessary to educate the public on the need for a citywide zoning plan and the concurrent requirement that aesthetics make up part of that plan. One should not necessarily allow the planners to implement their own concepts of what constitutes the public interest, but should, perhaps by survey and voting, determine what the community itself desires and how much it is willing to pay for it. What is needed is an open and thorough discussion of different concepts of aesthetics and their relative merits, not the imposition of the tastes of one class on another. Once a desire for aesthetics is expressed, reasonable standards for determining what is aesthetically valuable must be established. The community requires clear and flexible zoning regulations reflective of the wishes of the people that are neither so rigid as to produce monotony nor so loosely drawn as to be subject to arbitrary enforcement.[46]

The determination of standards and desires for a community is admittedly a lengthy and expensive process. But without the support of the community the implementation of aesthetic goals might be either fragmented or dictatorial. Within the scheme of aesthetic zoning, cognizance should be taken of minority rights and individual diversity. If only for the above reason, the community interest must be determined in a democratic manner. In the United States, with its divergent racial and ethnic backgrounds, different communities will demonstrate a variety of ideas as to what constitutes beauty.

The difficulty in encouraging diversity within an aesthetic framework

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44. Lionshead Lake v. Wayne Township, 10 N.J. 165, 89 A.2d 693 (1952). *See also* Annot., 95 A.L.R.2d 716 (1964) and Annot., 96 A.L.R.2d 1409 (1964).
45. Jasper v. Ky., 375 S.W.2d 709 (Ky. 1964).
46. Euclid v. Ambler Realty Co., 272 U.S. 365, 387 (1926).

is illustrated by *Reid v. Architectural Board of Review*,[47] where an ordinance provided that building plans be submitted to an architectural board of review for approval before a building permit would be issued. The board found that a one story home of a design substantially different than the surrounding two story residences did "not maintain the high character of community development in that it did not conform to the character of the houses in the area." The dissenting opinion focused on the true issues:

> Should appellant be required to sacrifice her choice of architectural plan for her property under the official municipal juggernaut of conformity in this case? Should her aesthetic sensibilities in connection with her selection of design for her proposed home be stifled because of the apparent belief in this community of the group as a source of creativity? Is she to sublimate herself in this group and suffer the frustration of individual creative aspirations? Is her artistic spirit to be imprisoned by the apparent beneficence of community life in Cleveland Heights?[48]

Closely associated with the issue of individual rights, is the enormous problem of who should assume the financial responsibility of beautifying the community. In looking at the decisions one can see that in some cases a substantial financial loss to the property owner resulting from a zoning ordinance was more than the judges could accept.[49] The issue of who will incur the cost of preserving beauty is also raised by the growing number of historical districts utilized in an effort to control land use where the municipality lacks the funds to acquire historic sites in eminent domain proceedings. Perhaps the individual whose absolute right of property ownership is infringed upon in order to make the community more beautiful should be compensated by that community.[50] Since the community would benefit from the attractive and pleasant surroundings it should be called upon to make good the loss of market value caused by the implementation of aesthetic zoning regulations.

A stinging indictment of aesthetic zoning concepts is found in Judge Van Voorhis' dissenting opinion in *People v. Stover*.

> Zoning, important as it is within limits, is too rapidly becoming a legalized device to prevent property owners from doing whatever their neighbors dislike. Protection of minority rights is as essential to democracy as majority vote. . . . Even where the use of property

47. 119 Ohio App. 67, 192 N.E.2d 74 (1963).
48. 119 Ohio App. 67, 76, 192 N.E.2d 74, 81 (1963).
49. *See* Pearce v. Edina, 263 Minn. 553, 118 N.W.2d 659 (1962). Here the zoning ordinance reclassifying plaintiff's property reduced its market value by approximately $200,000. The court held that the ordinance rendered the property valueless for many years and was "unreasonable, confiscatory, capricious and arbitrary" and had no valid relationship to issues of public health safety or welfare.
50. Euclid v. Ambler Realty Co., 272 U.S. 365 (1926).

> is bizarre, unsuitable or obstreporous it is not to be curtailed in the absence of overriding reasons of public policy. The security and repose which come from protection of the right to be different in matter (sic) of aesthetics, taste, thought, expression and within limits in conduct are not to be cast aside without violating constitutional privileges and immunities.[51]

Certainly beauty can be established without cheese box uniformity for an entire community. Yet, aesthetic concepts incorporated in construction and zoning ordinances impinge on individual freedom to utilize property in a manner contrary to the will of the community. Perhaps today's non-conformity, which may be termed architectural heresy, may be tomorrow's orthodoxy. As such, it should have its place within today's plan for the implementation of aesthetic considerations in zoning.

From a legal standpoint, if zoning ordinances which implement a policy of neighborhood amenity are to be stricken as invalid, it should not be because they seek to promote "aesthetic objectives" but rather because the restrictions constitute unreasonable devices of implementing community policy.[52] Consequently, if one is to follow the above reasoning, an ordinance should be declared invalid only when it constitutes an arbitrary or capricious method of attaining an attractive and efficiently operating community, and not upon the ground that the goal was primarily aesthetic. Thus, an ordinance emphasizing aesthetics should be judged on its reasonableness in achieving the goal of public welfare, and should not be automatically and narrowly categorized and judged unlawful on the basis of a superficial and unquestioned characterization.

III. Conclusion

It is time the courts recognize that the beauty of our communities is a legitimate end in itself. If it is a reasonable desire to have future generations grow up in more beautiful surroundings we must be willing to allocate funds and sacrifice some of our individual freedom for the good of the community. What is done today in land use planning will determine the landscape of the future. Should we fail to act in a unified, well directed manner in our demand for aesthetic concepts in zoning ordinances the eyesores of today will exist and multiply in the years to come.

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51. 12 N.Y.2d 462, 472, 191 N.E.2d 272, 278, 240 N.Y.S.2d 734, 742 (1963). *Also see* Van Voorhis' dissent in Presnell v. Leslie, 8 N.Y.2d 384, 394, 144 N.E.2d 281, 287, 165 N.Y.S.2d 488, 497 (1957) where he stated, "The urge toward conformity in modern society tends to compress people into uniform moulds and pressures of this nature beat hard upon zoning boards and municipal legislation bodies."

52. Dukeminier, *Zoning for Aesthetic Objectives: A Reappraisal,* 20 Law & Contemp. Prob. 218, 231 (1955).

Planning Department <planning@edcgov.us>

FW: Saratoga Retail Phase 2 - DR-R18-0001 (email 3)

1 message

Brooke E. Washburn <BWashburn@murphyaustin.com> Thu, Aug 16, 2018 at 2:21 PM
To: "planning@edcgov.us" <planning@edcgov.us>

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Subject: RE: Saratoga Retail Phase 2 - DR-R18-0001 (email 3)

Attached, please find pdf documents that are collectively **Exhibit B**, substantial evidence submitted to demonstrate a significant impact to Aesthetics (Section A. of the public comment- previously submitted). Please add these documents to the public record for Saratoga Retail Phase 2 - DR-R18-0001.

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Subject: RE: Saratoga Retail Phase 2 - DR-R18-0001 (email 2)

Attached, please find pdf documents that are collectively **Exhibit A**, substantial evidence submitted to demonstrate a significant impact to Aesthetics (Section A. of the public comment- previously submitted). Please add these documents to the public record for Saratoga Retail Phase 2 - DR-R18-0001.

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From: Brooke E. Washburn
Sent: Thursday, August 16, 2018 12:21 PM
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Subject: Saratoga Retail Phase 2 - DR-R18-0001

Dear Charlene,

Attached is public comment submitted by affected and concerned residents with regard to a proposed project (Saratoga Retail Phase 2 - DR-R18-0001). Due to the size of the documentation to be submitted, I will send all attachments under separate cover. Kindly include all comments and attachments in the public record for the project (Saratoga Retail Phase 2 - DR-R18-0001), and submit the same to the commission in advance of the **August 23, 2018**, hearing.

Brooke E. Washburn

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7 attachments

Beyond Dieselgate (brand2016).pdf
1191K

Intergovernmental Relations (kamieniecki1991).pdf
753K

Place-Based Stressors (kondo2014).pdf
388K

Traffic-related air pollution (jerret2014).pdf
850K

A Model for (mattingly).pdf
216K

Adoption and diffusion (nykiforus2018).pdf
2525K

An Evaluation of (hill2016).pdf
2729K

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Beyond 'Dieselgate': Implications of unaccounted and future air pollutant emissions and energy use for cars in the United Kingdom

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HIGHLIGHTS

- Explores the recent 'Dieselgate' affair and potential policy responses.
- Impacts on human health of 'real world' NOX emissions in the UK are significant.
- De-dieselization can have air quality benefits while showing few carbon disbenefits.
- Electrification shows largest 'co-benefits' but needs transformative approach.
- Electrification may mean faster decline in road tax revenues.

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ABSTRACT

The 'Dieselgate' emissions scandal has highlighted long standing concerns that the performance gap between 'real world' and'official' energy use and pollutant emissions of cars is increasing to a level that renders 'official' certification ratings virtually ineffective while misleading consumers and damaging human health of the wider population. This paper aims to explore the scale and timing of historic and future impacts on energy use and emissions of the UK car market. To achieve this aim it applies a bespoke disaggregated model of the transport-energy-environment system to explore the impacts of retrospective and future policy scenarios on the UK car market, trade-offs between greenhouse gas and air quality emissions, and fuel use and associated tax revenues. The results suggest that the impacts on human health of 'real world' excess NO_X emissions in the UK are significant. Future 'low diesel' policies can have significant air quality benefits while showing few (if any) carbon disbenefits, suggesting future car pricing incentives may need to be rebalanced taking more account of effects of local air pollution. Car pricing incentives are however unlikely to transform the car market without additional market changes, industry push, infrastructure investment and policy pull aimed at cleaner, lower carbon vehicles.

1. Introduction

1.1. The challenge – and potential opportunity?

The 'Dieselgate'[1] emissions scandal has highlighted growing concerns that the performance gap between 'real world' and 'official' energy use and air pollutant emissions of road vehicles is increasing to a level that renders 'official' certification ratings virtually ineffective while misleading consumers and damaging human health of the wider population. While real world CO_2 emissions have been shown to be on average a third higher (CCC, 2015b; ICCT, 2014a; TandE, 2015a), NO_X emissions can be up to 40 times higher than official certification values and standards operating in the EU (Hagman et al., 2015; ICCT, 2014b; Weiss et al., 2012), the US (Barrett et al., 2015) and China (Lau et al., 2015; Shen et al., 2015). For CO_2, the gap between test results and real-world

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[1] While there is no official definition of the term 'Dieselgate', it has become synonymous with the use by the Volkswagen Group of a 'defeat device' that detects when a diesel car is undergoing an official emissions tests and optimises engine performance to minimise air pollutant emissions to meet stringent emissions regulations. The device is only activated during the official test. Vehicles by other manufacturers have also been shown to exceed emissions in real world driving conditions; however, there has been no evidence of 'defeat devices' being used outside Volkswagen.

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performance has increased from 8% in 2001–31% in 2012 and 40% in 2014 (TandE, 2015a). Up to nine out of ten diesel cars on Europe's roads are said to break European NO_X pollution limits,[2] and the current generation of Euro 6 vehicles have been shown to emit, on average, seven times more NO_X than certified European values (Beevers et al., 2012; Dehmer, 2015; ICCT, 2014b). While the emissions scandal began in the US, little quantified evidence exists on the effects of excess emissions in the UK, which is a larger market for diesel cars. There is also a lack of quantification of the potential trade-offs between human health and climate change mitigation effects in the UK.

Given that transport accounts for 46 per cent of all NOx emissions in the region (EEA, 2015), the performance gap partly explains why NOx emissions in many European countries continue to miss targets (Beevers et al., 2012). The other reasons are the growth in overall traffic and the increase in the diesel market share for cars. In the UK, for instance, diesel vehicles accounted for fewer than 1 per cent of cars on the road in 1984 – last year that figure had risen to more than a third, with new registrations totalling about 1.35 million (or half) of all new cars in 2014 (SMMT, 2014). This compares to the almost 1.2 million VW diesel vehicles affected in the UK, and about 11 million VW diesel vehicles worldwide (Sheffield, 2015; Yeomans, 2015).

1.2. Lack of effective policy response in the UK

The human health 'costs' of diesel related air pollution (see Supplementary material S1 for further details) are highly policy-relevant. The UK Government has been subject to legal proceedings for failing to meet European Limit Values for NO_2, and their plans to reduce NO_2 concentrations and meet these limits was submitted to the European Commission at the end of 2015 (DEFRA, 2015a). Some major urban hotspots will continue to exceed EC limits for another decade to come (DEFRA, 2015a) as effective mitigation of local air pollution is proving to be an enormous challenge in cities across the globe (Barrett et al., 2015; Carrington, 2016; Walton et al., 2015; Woodcock et al., 2009). The policy response so far has been slow and ineffective as the reliance on updating the vehicle type-approval testing procedure and associated legislation are still on-going (CCC, 2015b) and will not have significant effects for another decade or more.

The proposed policy and technological solutions include actions at national and local levels: a national diesel car scrappage scheme; a ban on (older) diesel vehicles in cities; the requirement for new taxis to be ULEV by a certain date; rebalancing of national fuel duty and road tax (Vehicle Excise Duty, or VED) consistent with reducing not just CO_2 emissions but also NO_2 and particulate matter (PM); and national monetary incentives for switching to cleaner vehicles including ultra-low emission cars, taxis, vans and buses (DEFRA, 2015b; UK EAC, 2015). The quantified effects of these measures in the UK are largely unknown.

Partly fuelled by the 'Dieselgate' affair, the electrification of transport has gained further momentum, with Germany announcing it is to provide financial incentives of around €5000 for people to buy electric cars (EurActiv, 2015a, 2015b) and the UK extending its plug-in vehicle grant (£5000 per ULEV) that has led to a 1% take up of plug-in vehicles amongst total new vehicle registrations of 2.6 million in 2015 (SMMT, 2016). Some commentators suggest that continuing reductions in battery prices will bring the total cost of ownership of plug-in vehicles below that for conventional-fuel vehicles by 2025, even with low oil prices (BNEF, 2016). However, doubts remain whether plug-in vehicles are direct replacements of incumbent technologies or perceived as higher risk investments, thus limiting potential take-up (AEA Technology, 2009; BERR and DfT, 2008; Offer et al., 2011).

Some commentators are favouring a diesel scrappage scheme similar to that of 2009/10, with diesel car owners being offered up to £2000 to scrap their car and buy an ultra low emission vehicle (ULEV) instead (Cellan-Jones, 2015; Kollewe, 2015a; Vaughan, 2014). However, such a scheme may come at a cost to the taxpayer in the hundreds of millions (Vaughan, 2014) and may be considered unfair as it constitutes a direct subsidy to existing car owners. Moreover, as diesel vehicles emit 15–20% less CO_2 than a petrol equivalent, they have also made a significant contribution to climate change mitigation – an argument that was explored in this paper by investigating the trade-offs between meeting air quality and climate change objectives (Kollewe, 2015b; van der Zwaan et al., 2013; Vaughan, 2016).

1.3. Aims and objectives of this paper

This paper addressed the above challenge and potential policy and market solutions in two ways. First, it quantified the human health impacts and associated costs of 'real world' excess NO_X emissions in the UK context and compare this with an alternative pathway simulating a retrospective purchase penalty for diesel cars between 2009 and 2015. Second, it quantified the NO_X-related human health and climate change mitigation impacts of future policy scenarios aimed at the UK diesel car market.[3] This paper thus aims to fill existing gaps in the work going on relating to the assessment of 'real world' vs 'official' emissions and potential policy responses elsewhere which: (a) ignores the potential trade-offs between human health and climate change mitigation impacts; (b) lacks detailed analysis of how policy and market signals can change the evolution of the car market; (c) ignores wider fuel and/or vehicle life cycle emissions impacts in comparing different pathways; and (d) lacks investigating the impacts on transport fuel use and associated tax revenues.

2. Approach, methods and data

2.1. Approach and choice of modelling tool

To achieve the above aims the study applied an existing and previously published transport-energy-environment modelling framework that has been applied in a number of policy modelling studies (Anable et al., 2011; Anable et al., 2012; Brand et al., 2013; Brand et al., 2012). The UK Transport Carbon Model (UKTCM) was the tool of choice for this analysis because it integrates a household car ownership model, vehicle consumer choice model, vehicle stock evolution model and vehicle and fuel life cycle emissions model in a single scenario modelling framework. The integrated transport sector tool is able to provide policy-focused conclusions which allow an assessment of the effectiveness of different policy instruments (including regulation, pricing and availability of charging infrastructure) on different vehicle *and* consumer segments. UKTCM has the ability to place the 'de-dieselization' and electrification of the car market in the context of other (low carbon) transport behaviours on the basis of their whole life cycle emissions and impacts on human health, including potential changes in the way in which cars are used, together with

[2] European emission standards for vehicles http://ec.europa.eu/environment/air/transport/road.htm

[3] This paper focused on NO_X pollution and standards as this was the issue surrounding the Dieselgate affair. It is important to note that the inclusion in the damage cost calculation of other pollutants, notably PM, may change the damage cost values. Since total multi-pollutant valuations were likely to increase the totals, the figures reported in this study can be considered on the conservative side.

the impacts on government tax revenue. It may therefore have a much broader remit and wider range of applications in scenario and policy analyses than, for instance, the top-down 'ASIF' (Schipper, 2011) decomposition framework, sectoral models that lack endogenizing consumer behaviour (Fontes and Pereira, 2014; Rogan et al., 2011), or integrated assessment models that by and large favour technology solutions and fuel shifts over travel activity and consumer behaviour modelling (Creutzig, 2015; Oxley et al., 2013).

The modelling framework was first applied in a UK case study to quantify the implications of the performance gap between 'real world' and 'official' energy use and air pollutant emissions of EURO5 and EURO6 diesel cars. In a forward looking modelling exercise it was then applied to explore the energy and emissions impacts of alternative policy scenarios of a CO_2-graded purchase/scrappage tax on diesel cars and an ambitious electrification pathways for UK car fleet. The modelling framework is briefly summarised below followed by describing the core methods, data and assumptions for the scenario portfolio used in this study.

2.2. The UK Transport Carbon Model (UKTCM): outline and key methods

The UKTCM is a highly disaggregated, bottom-up modelling framework of the transport-energy-environment system. Built around a flexible and modular database structure, it models annual projections of transport supply and demand, for all passenger and freight modes of transport, and calculates the corresponding energy use, life cycle emissions and environmental impacts year-by-year up to 2050. It takes a holistic view of the transport system, built around a set of exogenous scenarios of socio-economic, socio-technical and political developments. The model is technology rich and, in its current version, provides projections of how different vehicle technologies evolve over time for 770 vehicle technology categories,[4] including 283 car technologies such as increasingly efficient gasoline internal combustion engine (ICE) vehicles, hybrid electric vehicles (HEV), battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and hydrogen fuel cell vehicles (HFCV). UKTCM played a key role in developing the *Energy2050* 'lifestyle' scenarios (Anable et al., 2011; Anable et al., 2012) for the UK Energy Research Centre (UKERC) and in exploring the effectiveness of low carbon car purchasing incentives in the UK (Brand et al., 2013). An overview of the model has been published in Brand et al. (2012). For the analysis presented in this paper, UKTCM was developed, updated and recalibrated from version 2.0 (as reported in Brand et al., 2013) to the current version 3.1.

Car technology evolution, use and impacts are modelled in four areas of modelling: (1) the car ownership model, (2) the car sales, choice and use model, (3) the direct energy use and emissions model and (4) the life cycle energy and environmental impacts model.

2.2.1. Modelling car sales, technology choice and use

New car sales are a function of total car ownership and car scrappage, with the latter modelled as a function of average life expectancy via a S-shaped (modified Weibull) scrappage probability curve (Brand, 2010; Brand et al., 2012). The new car market is first segmented into private and company/fleet markets, then into three vehicle segments according to common definitions of car size and class (A/B – 'small', C/D – 'medium', E/F/G/H – 'large'). Using UK data to illustrate the segmentation, Fig. 1a shows the sales by ownership and size in 2013, highlighting the significance of the fleet/company market (52.5% of all new cars). This is an important distinction for modelling the car market as the fleet/company segment has historically been dominated by diesel car technology, and plug-in vehicles now taking in-roads in the same segment, but in smaller sizes. Fig. 1b shows the split by ownership and consumer segment, following the approach used by Element Energy and Aberdeen University for the Energy Technologies Institute in the UK (Element Energy, 2013).

The UKTCM's car choice model is a discrete choice model that estimates the purchase choice probability based on an assessment of overall vehicle 'attractiveness' (or 'utility') from amongst a set of vehicle choices (or 'alternatives'), each with their own financial and non-financial 'attributes'. The weighting of attributes varies across consumer segments, because consumers' opinions on the importance of different vehicle attributes vary. The model therefore reproduces the variation in utility of different vehicles across consumer segments, and the variation over time as vehicle attributes improve. The choice model was run for each vehicle segment and consumer segment, with the share of vehicle and consumer segments being kept constant in the Reference (REF) case. The modelling methods are described in more detail in the Supplementary material S2.

2.2.2. Energy and emissions from vehicle operation

In-use energy consumption (in volume and energy units) and air pollutant emissions (in tonnes of CO_2, NO_X, PM, CH4, NMVOC, and so on) from motorised travel were computed by using disaggregate sets of emission factors, which were based on the results of large scale vehicle emissions testing programmes. For road transport, speed distributions for each vehicle type (car, motorcycle, van, HGV) and road segment type (urban, rural, motorway) were used to calculate energy consumption and emissions, based on average speed-emissions curves developed in previous research and emissions inventories such as COPERT II and III (EEA, 1998, 2000), MEET (Hickman et al., 1999), HBEFA (INFRAS, 2004) and NAEI (NETCEN, 2003). Emissions factors for road vehicles at normal operating temperatures (often called 'hot') were a polynomial function of average speed, with up to ten coefficients for each pollutant. The fitted average-speed emissions curves typically resemble U-shapes, with NO_X emissions curves showing relatively higher emissions at speeds above 100 km/h. The road transport module also takes account of 'cold start' effects, which mainly depend on ambient temperatures and trip distances. The approach allowed us to model the combined effects of different fleet compositions, different sets of emission factors (e.g. 'official' vs 'real world'), traffic characteristics, cold starts, fuel quality and driver behaviour. The UKTCM Reference Guide (Brand, 2010) describes the functional relationships in detail. 'Official' NO_X and CO_2 emissions factors and electricity consumption for cars are given in Supplementary material S3.

2.2.3. Life cycle energy use, emissions and impacts

Based on a typical environmental life cycle assessment framework (ICO, 2006), the UKTCM includes a life cycle inventory model and an environmental impacts assessment model. The former computes energy use and emissions (including primary energy and land use) from the manufacture, maintenance and disposal of vehicles; the construction, maintenance, and disposal of infrastructure; and the supply of energy (fuels). The latter then provides an assessment of the damage caused by calculating impact indicators and external costs. The life cycle inventory model uses the 'hybrid approach' of process-chain analysis and input-output analysis (Marheineke et al., 1998). Process chain analysis is used for the main supply paths, and aggregated values for complete

[4] A UKTCM 'vehicle technology category' is defined as a typical representative of a combination of transport type (passenger or freight), vehicle type (e.g. motorcycle, car, HGV, train), vehicle size (e.g. small car of segment A/B, van, heavy truck, intercity rail), primary fuel type (e.g. gasoline, diesel, electricity), vintage (e.g. ICE Euro 5 2009–15, PHEV 'Euro 7' 2020–25) and hybridisation (ICE, HEV, PHEV). 'Vintaging' is used to simulate changes in performance, efficiencies, consumer preferences, costs and policy levers over time.

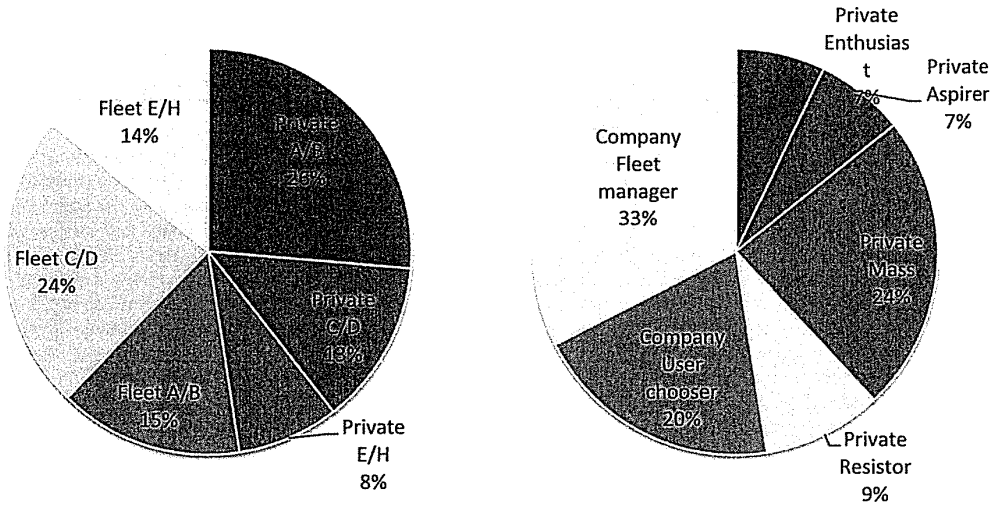

Fig. 1. a/b: Car sales (a: left) and consumer split (b: right) in the UK market (2013 data).
Source: adapted from SMMT (2014), Element Energy (2013) and ETI (ETI, 2014)

Table 1
Damage costs per ton (2015 prices) for NO_X and $PM_{2.5}$ by population density.Source: DEFRA (2015a)

Population/building density	NO_X damage costs [£/ton][a]			$PM_{2.5}$ damage costs [£/ton]		
	Low[b]	Central	High[a]	Low[a]	Central	High[a]
High ('transport inner conurbation')	20,455	**51,137**	81,820	110,590	**141,248**	160,507
Medium ('transport average')	8417	**21,044**	33,670	45,510	**58,125**	66,052
Low ('rural')	2610	**6524**	10,438	14,108	**18,020**	20,476

Notes:

[a] The central sensitivities reflect uncertainties around the lag between exposure and the health impact. The sensitivity for NO_X also reflects the uncertainty around the link between NO_2 exposure and mortality.

[b] NO_X damage costs if $PM_{2.5}$ is also valued (per ton, 2015 prices).

process chains are used within the model. For additional upstream processes, considered to be second or third-order effects, input-output analysis is used. This hybrid approach is seen as appropriate as much of the evidence in the literature suggests that, in most cases, over the lifetime of a vehicle, vehicle operation produces the vast majority of energy use and emissions (Bastani et al., 2012; Lane, 2006; MacLean and Lave, 2003; Ogden et al., 2004; Sperling and Yeh, 2010). While the fuel supply and vehicle manufacture stages typically account for about 20% of total lifetime GHG emissions – being roughly equal in magnitude – vehicle maintenance and disposal account for a much smaller share (ibid.).

The methodology for determining external costs is based on an evaluation of marginal effects (marginal external costs/benefits), which were estimated using the Impact Pathway Approach developed previously in European research (Bickel et al., 2003; EC, 2005; Rabl and Holland, 2008; Rabl et al., 2014) and is commonly used in transport modelling and appraisal (DfT, 2014a; Macharis and Bernardini, 2015; Michiels et al., 2012; Mulley et al., 2013). For instance, average damage costs to human health of direct NO_X and $PM_{2.5}$ emissions by population density are shown in Table 1 below.[5] The UKTCM Reference Guide (Brand, 2010) describes the functional relationships and data used in detail.

[5] The full Impact Pathway (IPA) modelling is relatively resource and time intensive. To support decision making, damage costs per ton of emissions were developed by DEFRA for use by analysts. These damage costs were derived from the full IPA analysis, providing a proportionate approach to valuing of the impacts of changes in air quality.

2.2.4. Limitations of the approach used

There are some important limitations and uncertainties in the approach. The data underlying the car choice model used in the future scenario analysis are based on stated preference and 'what-if' type assumptions on exogenous factors. More up-to-date evidence is needed on the characteristics, behaviours and attitudes of current diesel, gasoline and EV owners in the UK (towards revealed preference). In order to keep pace with the rapid development of the market and inform future policy making aimed at limiting damage to health from diesel vehicles and at the same time supporting the growth of the EV market, evidence on vehicle ownership and use should ideally be collected on a continuous or semi-regular basis (Brook Lyndhurst, 2015). This study has adopted a relatively simple analysis of linking emissions with impacts, the marginal damage costs approach based on aggregated results using the more detailed impact pathway approach. While the limited sensitivity analysis around the key factors determining damage costs on human health helps to explore the underlying uncertainty, further work may be required on impact modelling at the roadside and local levels, e.g. by linking place-based models such as UKTCM with integrated assessment models as has been done in some notable UK studies on cross-sectoral implications and climate 'co-benefits' in road transport pollution abatement (Oxley et al., 2015; Oxley et al., 2013; Oxley et al., 2012; Oxley et al., 2009).

2.3. The UK case study – modelling 'official' and 'real world'

pollutant emissions

2.3.1. Reference pathway (REF) – key data and assumptions

UKTCM v3.1 was calibrated to UK national statistics for the year 2013 (DfT, 2014b). The base case or 'Reference scenario' (REF) broadly depicts a projection of transport demand, supply, energy use and emissions as if there were no changes to transport and energy policy beyond October 2015. It was modelled using UKTCM based on exogenous assumptions and projections of socio-demographic, economic, technological and (firm and committed) policy developments, including the complex CO_2-graded road tax[6] and company car tax regimes. Economic growth data up to 2014 were based on UK government figures. Future GDP/capita growth were assumed to average 1.7% p.a. up to 2050 – in line with the historic 50-year average for the UK. Transport demand projections were modelled based on average demand elasticities (of GDP/capita, population and generalised cost) for the 1995–2014 period. Fuel price and retail electricity price projections were based on 2014 UK Government forecasts (DECC, 2014). Vehicle Excise Duty (VED, i.e. annual road tax) and other fuel duties were assumed to remain constant at 2015 levels. Following an approach commonly used in technology futures and modelling studies (European Commission, 2005; Fulton et al., 2009; Strachan and Kannan, 2008; Strachan et al., 2008; UK Energy Research Centre, 2009; WEC, 2007), pre-tax vehicle purchase costs were kept constant over time for established technologies and gradually decreased for advanced and future technologies, thus exogenously simulating improvements in production costs, economies of scale and market push by manufacturers.[7] For example, average purchase prices for BEV cars were assumed to decrease by 2.8% pa from 2015 to 2020, by 1.6% pa until 2030 and 0.6% pa until 2050. The Reference scenario further assumed gradual improvements in specific fuel consumption and tailpipe CO_2 emissions per distance travelled. The rates of improvement were based on technological innovation driven entirely by market competition, not on policy or regulatory push.[8] Fuel consumption and CO_2 improvement rates for future car vintages were assumed to be 1.5% pa (a somewhat lower and more conservative rate than the average rate of 4% pa observed for all new cars between 2008 and 2013). Indirect emissions from fuel supply and vehicle manufacture, maintenance and scrappage have been updated with data from a recent UK based review (Kay et al., 2013). Finally, the default electricity generation mix follows central government projections (mainly natural gas, wind and nuclear – with some CCC coal and gas by 2030), implying the carbon content of retail electricity is gradually decreasing from about 390 gCO_2/kWh in 2015 to about 160 gCO_2/kWh in 2030 (then staying constant to 2050).

2.3.2. Retrospective pathways exploring unaccounted for emissions

Two retrospective pathways coined Real World (RW) and Real World plus Diesel Purchase Penalty (RW_DPP) were developed to assess unaccounted-for emissions from diesel cars and the wider effects on energy use and GHG emissions in the UK. First, scenario RW simply assessed the UK-wide implications of the gap between 'official' and 'real world' NO_X emissions by assuming that all EURO5 and EURO6 diesel cars (not just VWs) bought and used in the UK since 2009 perform 4 times worse than official ratings suggest. Thus, EURO5 diesel cars emitted on average 0.72 gNO_X/km instead of 0.18 gNO_X/km; and EURO6 cars emitted on average 0.32 gNO_X/km instead of 0.08 gNO_X/km. This factor 4 is in line with the real world test data for EURO5 cars reported in ICCT, (2014b). For EURO6 cars it is, however, on the conservative side as the average gap between official and real word was reported to be higher at a factor of 7 (ibid). In terms of market shares, sales data for the UK show that VW had a 20.5% market share in the UK in 2013 (SMMT, 2014), so the factor 4 assumption implies that VW cars of that generation performed about 20 times worse than expected – which falls into the reported range of between 5 and 35 times. Any future EURO standards and performance gaps beyond EURO6 (so from about 2020 onwards) are currently uncertain, so it was assumed that any future vintages (labelled 'EURO7' from 2020 to 2024, 'EURO8' from 2025 to 2029, and so on) would meet emissions standards of at least EURO6 in 'real world' conditions. This was considered a reasonable assumption given the increased efforts to improve real world performance by industry and government and the likely tightening of standards beyond EURO6.

Second, to explore how consumers may have responded if they had known about the gap in emissions performance, an alternative 'what if' scenario (RW_DPP) was developed that modelled a 'purchase penalty' of GBP 2500 for all new EURO5 diesel-fuelled cars (ICE, HEV and PHEV) from 2009 to 2015. The penalty fee of GBP2,500 was estimated from summing up annual car mileages over the lifetime of a vehicle (~180k kilometres over 10 years), then multiplying this by the difference in NO_X emissions between 'real world' and 'official' rates (0.72–0.18=0.54 gNO_X/km) and the average damage costs of NO_X on human health of GBP 21,044 per ton (Table 1) (DEFRA, 2015a). By placing a penalty at the time of purchasing a diesel car the study effectively explored a recent past with lower diesel car market shares and different energy use and emissions when compared to the 'real world' case (RW). The core scenarios are summarized in Table 2.

2.3.3. Forward looking pathways exploring the effects of potential policy and market responses

Recent pronouncements by market analysts, city authorities and business leaders (e.g. BBC News, 2015; TfL, 2015) have supported policy measures such as diesel scrappage fees and promotion of ultra-low emissions vehicles (ULEV) and a switch to electro mobility to reduce the damage to human health by (underperforming) diesel cars (EurActiv, 2015b). Three further scenarios were developed to explore future policy and market responses. First, scenario REF' depicts a 'revised baseline' for comparison by assuming that all existing and future diesel cars underperform by a factor of 4 when compared to legislated standards (from EURO6 in 2015 onwards).[9] This is at the lower end of the reported range of 4–20 times higher NO_X for EURO6 type approved private cars with diesel engines in city traffic and during cold weather (Hagman et al., 2015). In essence this depicts a future where NO_X emissions control will not be achieved as planned. Second, DPT explores the effects of a variable scrappage/purchase tax on new diesel cars, with the tax graded by the vehicle's purchase price and specific fuel consumption (Tax~[purchase price]* [specific fuel consumption, SFC]). In 2015, the graded tax ranged from approx. GBP800 for small (A/B class) diesel cars to approx. GBP2,500 for large (E-H class) ICE diesel cars, with the tax gradually decreasing due to improved SFC. Purchase taxes in this range have shown to be fairly effective in accelerating change in vehicle uptake in the low carbon context (Brand et al., 2013). Third,

[6] In the UK this is called 'vehicle excise duty', or VED.

[7] The assumption that alternative technologies improve (cost, energy and environmental performance, consumer preferences) at a faster rate over time applies equally to all scenarios modelled here, not just the reference scenario.

[8] This implies that the EU mandatory agreement on new car CO_2 emissions would not be met. However, separating innovation by competition and innovation by regulation/policy push is slightly arbitrary here as the effects are never easy to untangle. It was merely assumed that half of the recent improvement came from market competition and the other half from policy (mainly fiscal) and regulation.

[9] This compares to the REF case assuming that only EURO5 and EURO6 diesel cars underperformed in real world driving conditions.

Table 2
Overview of core scenarios.

		Scenarios		
		Baseline for comparison	*Alternative 1*	*Alternative 2*
Type of analysis	**'Retrospective' (from 2009)[a]**	*REF*: reference scenario of transport demand, supply, energy use and emissions as if there were no changes to transport and energy policy	*RW*: EURO5 and EURO6 diesel cars emit 4 times the regulated amount (both 'hot' and 'cold start' emissions)	*RW_DPP*: as *RW* but with a purchase penalty of GBP2,456 per EURO5 diesel car, from 2009 to 2015 only
	Forward looking (from 2015)[b]	*REF*': adjusted baseline assuming all future diesel cars emit 4 times the regulated (EURO6+) amount	*DPT*: as *REF*' but with a scrappage/purchase tax on diesel cars, graded by purchase price and 'official' fuel economy	*DPT_EV*: combined *DPT* with 'high electrification' pathway (supply side measures + pricing)

Notes:
[a] Both RW and RW_DPP assumed that only EURO5 and EURO6 diesel cars emit 4 times the regulated amount through their lifetimes, from first take-up in 2009 until they are eventually scrapped (i.e. well into the late 2020s).
[b] In contrast, all forward looking scenarios assumed that all future diesel cars emit 4 times the regulated amount.

in order to compare the above with a high electrification, low dieselization pathway, scenario DPT_EV combined the above scrappage/purchase tax (DPT) with a transformative pathway developed for the UK's Committee on Climate Change (CCC) and focusing on supply measures for plug-in vehicles as an alternative to diesel cars. The analysis by the CCC (CCC, 2013, 2015a) suggested plug-in vehicle deployment targets for 2020 and 2030 at 9% and 60% respectively. A small number of scenarios were run using UKTCM in an iterative process that led to the high electrification scenario underlying DPT_EV. This implied transformational change including: ULEV being available in all vehicle segments and by all major brands by 2030; nationwide consumer awareness and acceptance of ULEV by the 2030s; significant investment and repositioning towards ULEV by the main vehicle manufactures; significant investment in recharging infrastructure; reduced (perceived) recharging times; and continued and improved equivalent value support for ULEVs for both private and company/fleet buyers.

2.3.4. Sensitivity analysis

In order to assess uncertainty in the economic valuation estimates a limited sensitivity analysis was conducted, including testing a range of low and high values (Table 1) for air quality damage costs of NO_X emissions in line with UK government guidelines used to assess national policies, programmes and projects (DEFRA, 2015a).

3. Results

This section presents the results structured by the main findings on the impacts on human health (Section 3.1), the future car market evolution (Section 3.2), the trade-offs between GHG and air quality emissions (Section 3.3), and the impacts of future policy on fuel use and associated tax revenues (Section 3.4).

3.1. The impacts on human health of unaccounted-for NO_X emissions could be significant

The retrospective analysis suggests significant impacts on human health that have not been accounted for using 'official' NO_X emissions ratings. When comparing RW with REF, 'real-world' NO_X emissions from Britain's car fleet were 12 Kilo-tonnes of NO_X ($KtNO_X$) (+6%) higher in 2009 (the first year of the EURO5 period) when compared to 'official' rating values, rising steadily over the following ten years to 72 $KtNO_X$ (+137%) in 2019 when the diesel car stock of the EURO5 and EURO6 generations would peak (see green lines/bars in Figs. 2 and 3).

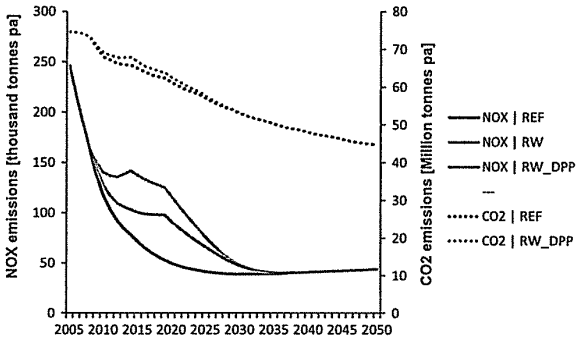

Fig. 2. : Retrospective gap analysis, total NO_X and CO_2 emissions from cars, 2005–2050 Notes: For NO_X emissions read left y axis; for CO_2 emissions read right y axis.

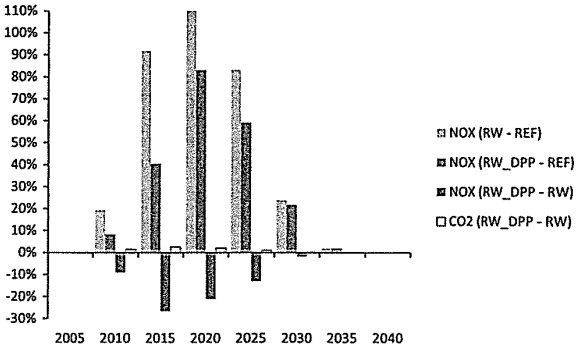

Fig. 3. : Retrospective gap analysis, differences between scenarios in tailpipe NO_X and CO_2 emissions from cars, 2005–2040 Notes: REF=Reference scenario; RW=Real World scenario; RW_DPP=Real World and Diesel Purchase Penalty scenario.

The associated marginal damage cost to human health in 2009 was £356 million p.a. (low £142 million, high £569 million) rising to £2.13 billion p.a. (low £852 million, high £3.41 billion) in 2019. Between 2009 and 2039 the additional damage costs of 'real world' NO_X totalled £29.1 billion (low £11.6 billion, high £46.5 billion). While these are big numbers, they are considerably lower than the total economic cost from the impacts of air pollution in the UK of around £20 billion every year (RCP, 2016), which is also comparable to the wider economic cost of obesity of up to £27 billion p.a. (Morgan and Dent, 2010). The damage costs are also smaller than annual tax revenues from diesel cars that have were estimated in this study at around £5.6 billion in 2015 (see Fig. 9).

An emissions related purchase price premium on diesel cars (as in RW_DPP) could have avoided about 43% (a total of 419 $KtNO_X$) of the 'real world' gap in NO_X emissions if consumers had perceived diesel cars as being more damaging to health and chosen higher shares of alternative drivetrains to diesel ICEs (NB: RW_DPP was compared with RW here). However, a fleet with fewer diesels would have emitted somewhat higher tailpipe CO_2 emissions, with the difference to baseline peaking at 2.2 Million tons of CO_2 ($MtCO_2$) per year in 2014 (or 3.3% of direct CO_2 emissions from cars) and summing up to 23.1 $MtCO_2$ between 2009 and 2030. By comparing RW_DPP to RW (i.e. fewer diesel cars in the fleet between about 2010 and 2030), the modelling suggests that the avoided damage cost to human health of £12.2 billion (low £4.6 billion, high £19.5 billion) clearly outweighed the carbon costs[10] of £607 million (low £243 million, high £971 million).

3.2. *A diesel purchase tax alone will not transform the car market without supply side measures aimed at clean vehicles*

The retrospective 'purchase penalty' showed a significant drop in the market share for diesel cars. While the baseline (REF) market share of new diesels rapidly increased from 27% in the early 2000s to about 45% in 2015, it was only about 19% during the six years the 'purchase penalty' was in place (RW_DPP). Most of the fuel shift in car purchasing was to gasoline ICV, with some shifting to gasoline HEV, resulting in the NO_X and CO_2 emissions changes shown above.

When switching focus to the forward-looking scenarios, the main effect of the graded purchase/scrappage tax on diesel cars (DPT) was a moderate shift in preferences from diesel (ICV, HEV) to conventional gasoline (mainly ICV but also some HEV) and plug-in vehicles (BEV, gasoline PHEV), particularly for the more price sensitive fleet/company car market. While diesel market shares in the baseline scenario (REF') stayed at just below 50% between 2015 and 2050, they were somewhat lower at 35% in DPT (or 26% lower than the REF' baseline), with gasoline ICV and BEV increasing their shares by about 25% each (Fig. 4).

In contrast to DPT, the DPT_EV pathway showed a marked transition from conventional ICV to ULEV from the mid 2020s onwards (Fig. 4). While new BEV and PHEV only made up 4% of the market share in 2020, this had risen to nearly half of all new cars being plug-in (39% PHEV, 9% BEV) by 2030. By 2050, the share had risen further to 60% (24% PHEV, 36% BEV). In contrast, new diesel ICV and diesel HEV sales dropped from nearly half in 2015–31% in 2020, 20% in 2030 and 17% in 2050.

The evolution of the *total* car fleet is shown in Fig. 5, suggesting that the 2020 stock will look pretty much the same as it is today. By 2030, the car fleet would include significantly fewer diesel ICV in the DPT case, and plug-in vehicles (mainly PHEV) would have taken significant shares away from ICVs and HEVs in the DPT_EV case. By 2050, the majority of the fleet would be plugged-in only if the UK adopted appropriate ULEV measures (as in DPT_EV but *not* in DPT). However, the modelling suggests that even higher ULEV uptake of the fleet of more than 60% is unlikely to materialize without further policy incentives (e.g. free parking, free electricity, new business models of EV ownership and use), supply shift to EV (e.g. decreasing model/brand supply of gasoline ICV cars) and regulation (e.g. eventually banning gasoline and diesel cars in urban areas).

[10] Carbon valuation was based on the 'social cost of carbon' (SCC) that measures the full cost of an incremental unit of carbon (or greenhouse gas equivalent) emitted now, calculating the full cost of the damage it imposes over the whole of its time in the atmosphere. The SCC was preferred over market prices (e.g. EU trading scheme) as the road transport sector is a non-traded sector. Values were taken from UK guidance, ranging from GBP 13.5/tCO_2e (Low) to 22.5 (central) and GBP 41.5/tCO_2e (High).

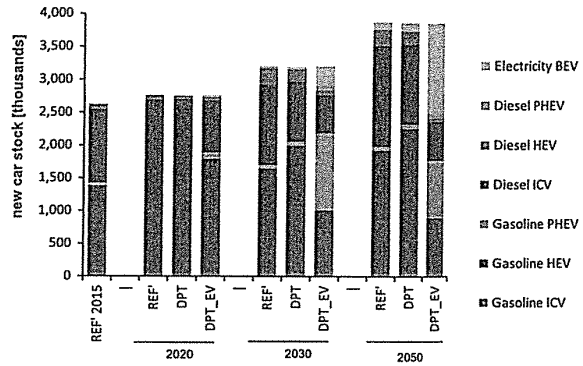

Fig. 4. : Scenario comparison of new car sales by propulsion system Notes: REF' 2015 refers to base year sales. REF'=Reference scenario (revised); DPT=Diesel Purchase Tax scenario; DPT_EV=Diesel Purchase Tax and EV package scenario. The analysis suggested no significant take up of hydrogen FCV, dedicated biofuel ICV and gas powered ICV, largely due to the assumed lack of any model/brand supply. Therefore, these propulsion systems were omitted from the chart.

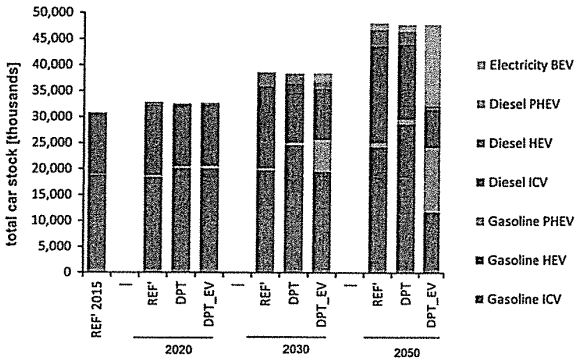

Fig. 5. : Scenario comparison of total car stock by propulsion system in 2020, 2030 and 2050 Note: REF' 2015 refers to base year sales. REF'=Reference scenario (revised); DPT=Diesel Purchase Tax scenario; DPT_EV=Diesel Purchase Tax and EV package scenario. The total stock of dedicated biofuel ICV, (LPG/CNG) gas powered ICV and hydrogen FCV was negligible (< 10 thousand), largely due to the assumed lack of any model/brand supply. Therefore, these propulsion systems were omitted from the chart.

3.3. *Future 'low diesel' policies and supply measures can have significant air quality benefits while showing few (if any) carbon disbenefits*

The results of the forward looking analysis suggests that policies designed to 'discourage' diesel sales and/or promote ULEV as cleaner alternatives can have significant impacts on air quality and carbon emissions (Figs. 6 and 7). When compared to the 'real world' baseline (REF'), the variable purchase/scrappage tax on new diesel cars (DPT) resulted in moderate NO_X emissions reductions, rising steadily from 1.1 $KtNO_X$ p.a. (0.8%) in 2015 – the first year of the policy – to around 16 $KtNO_X$ p.a. (15%) in 2025. The total avoided marginal damage costs to human health between 2015 and 2025 were £2.91 billion (low £1.04 billion, high £4.66 billion). Beyond 2025 the emissions savings levelled off then stayed roughly constant with average reductions of 18 $KtNO_X$ p.a. out to 2050, indicating a saturation of the policy's main effect of fuel switching away from diesel. In that period the annual avoided damage cost to human health due to reduced NO_X averaged £516 million p.a. (low £193 million p.a., high £826 million p.a.).

To achieve higher and *increasing* emissions savings and avoided

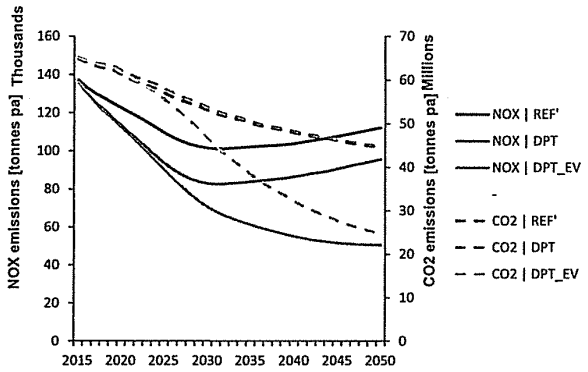

Fig. 6. : Future policy analysis, total NO_X and CO_2 emissions from cars, 2015–2050 Note: REF'=Reference scenario (revised); DPT=Diesel Purchase Tax scenario; DPT_EV=Diesel Purchase Tax and EV package scenario.

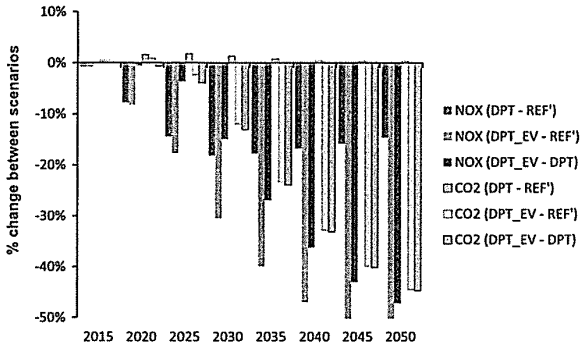

Fig. 7. : Future policy analysis, differences between scenarios in car NO_X and CO_2 emissions, 2015–2050 Note: REF'=Reference scenario (revised); DPT=Diesel Purchase Tax scenario; DPT_EV=Diesel Purchase Tax and EV package scenario.

damage costs beyond 2025 additional market changes, industry push, infrastructure investment and policy pull would be required as explored in DPT_EV. When compared to baseline (REF'), NO_X emissions in DPT_EV were lower at 31 $KtNO_X$ p.a. (−30%) in 2030 and 62 $KtNO_X$ p.a. (−55%) in 2050, by which time about three quarters of the reduction was due to the additional supply side measures (Figs. 6 and 7). Between 2025 and 2050 the total avoided damage cost of reduced NO_X emissions came to a substantial £35 billion (low £15 billion, high £56 billion).

In terms of carbon emissions the results showed that already in the forward-looking baseline case (REF') direct emissions of CO_2 from cars fell substantially, from the 2015 level of 65 $MtCO_2$ to 61 $MtCO_2$ in 2020, 53 $MtCO_2$ in 2030 and 45 $MtCO_2$ in 2050.[11] While the post-2008 economic downturn and rising fuel costs were major factors underlying the short term fall before 2015 (Fig. 2), the longer-term decrease of about 18% between 2015 and 2030 is largely the result of improvements in fuel efficiency and emissions performance of new cars penetrating the fleet and some fuel switching to HEVs and PHEVs, thus offsetting the overall growth in the demand for car travel. The diesel car purchase/scrappage tax (DPT) showed *higher* carbon emissions when compared to baseline (REF'), with the difference first increasing to 1.0 $MtCO_2$ by 2025 then gradually decreasing to 0.2 $MtCO_2$ by the 2040s (Fig. 7). As with the retrospective analysis, this was due to the lower share of (lower carbon) diesel cars in the fleet. As expected the combination of the diesel purchase/ scrappage tax with the higher uptake of ULEV in scenario DPT_EV yielded significant emissions savings from 2025 onwards, gradually reducing emissions from +0.6 $MtCO_2$ in 2018 to −6.4 $MtCO_2$ in 2030 and −19.9 $MtCO_2$ p.a. in 2050. DPT_EV thus achieved significant 'co-benefits' in the longer term by incentivizing and promoting cleaner and lower carbon alternatives to diesel cars.

As shown in the Supplementary material (S4), intra-scenario differences in *total life cycle* emissions impacts were not as significant as with direct emissions, as direct GHG emissions savings were being offset by gradual increases in indirect GHG emissions from the increase of emissions from upstream electricity generation. As expected, the biggest changes came from the radical (perhaps necessary from a climate perspective) changes in scenario DPT_EV.

3.4. Wider impact on energy use, fuel demand and fuel tax revenues

In the short term all scenarios showed only a small increase in overall energy use and a switch from diesel to gasoline (ICV, HEV), which can be explained by gasoline ICV being less energy efficient than diesel ICV (Fig. 8). In the medium to longer term the modelling showed modest (2030) to large (2050) fuel switching and decreases in energy consumption due to the uptake of more energy efficient propulsion systems in the form of plug-in vehicles (gasoline PHEV, BEV). The diesel purchase tax + high electrification scenario (DPT_EV) showed total fuel demand decreasing by up to 52% by 2050 when compared to 2015. This contrasts to a decrease of 31% in baseline scenario (REF') by 2050. By 2050, diesel demand drops from about half in the reference case (REF') to 35% (DPT) and 26% (DPT_EV). By comparison, electricity demand grows steeply in the DPT_EV scenario, particularly in the second half of the period, accounting for 21% of total energy consumption by 2050. However, in all scenarios, conventional fuels (gasoline + diesel) still dominate energy use, never falling below 79% of total demand.

In 2014/15, about £16.2 billion were raised from cars through road fuel tax, which was almost entirely from the duty on gasoline and diesel of £0.61/litre (DfT, 2015). As shown in Fig. 9, the results suggest that the road tax revenue stream would not change much in the short term. However, in the long term the modelling suggests that road tax revenues would fall sharply to about £11 billion

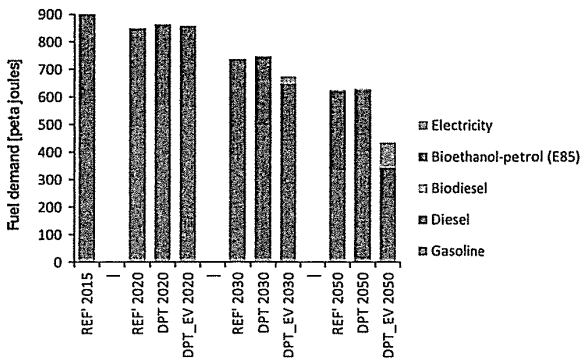

Fig. 8. : Pathways comparison of car transport fuel demand (in PJ) by transport fuel, 2020–2050. Note: The demand for LPG, CNG and hydrogen was negligible, largely due to the lack of any take up in the car fleet. Therefore, these fuels were omitted from the chart. REF'=Reference scenario (revised); DPT=Diesel Purchase Tax scenario; DPT_EV=Diesel Purchase Tax and EV package scenario.

[11] Changes in carbon emissions are the result of a number of interrelated factors, including the penetration of lower emission cars into the vehicle fleet, changes in demand for cars and other modes, changes in car total ownership (e.g. a decrease in total ownership means lower indirect carbon emissions from manufacture, maintenance and scrappage) and changes in upstream fuel emissions. For further details on how this is done in UKTCM see Brand (2010a/b) and Brand et al. (2012).

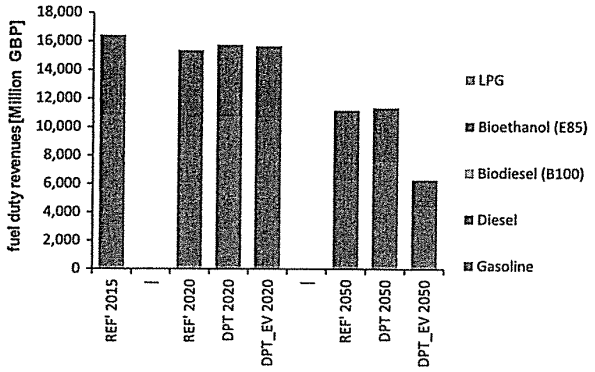

Fig. 9. : Pathways comparison of fuel tax revenues from cars (in £Million) by transport fuel – 2015, 2020 and 2050 Note: The demand for CNG and H_2 was negligible, largely due to the lack of any take up in the car fleet. Therefore, these fuels were omitted from the chart. REF'=Reference scenario (revised); DPT=Diesel Purchase Tax scenario; DPT_EV=Diesel Purchase Tax and EV package scenario.

p.a. (REF', DPT), and even lower to £6 billion p.a. in the high electrification case (DPT_EV), which while necessary in climate terms may limit the government's ability to pay for the health damage costs.

4. Conclusion and policy implications

4.1. Key results: 'real world' excess emissions

This study has quantified the human health impacts and associated costs of excess NO_X emissions in the UK context and found that the size and timespan of unaccounted-for NO_X emissions was significant, with up to more than double the amount of NO_X in the atmosphere than official ratings suggest. This is in line with recent studies that investigated air quality impacts of excess diesel emissions in the UK (Beevers et al., 2012; Dunmore et al., 2015; Walton et al., 2015). It is significantly higher than the most recent estimates of excess emissions in the US (Barrett et al., 2015), reflecting the different vehicle fleet compositions and emissions standards operating in the two countries. The additional damage costs of 'real world' NO_X in the UK were significantly higher than the US estimates reported in Barrett et al. (2015), reflecting differences in methodologies (valuation of 'indirect' $PM_{2.5}$ and ozone only in the US study), 'doses' and population densities. The impact valuation results of this study compare to the total economic cost from the impacts of air pollution in the UK of around £20 billion every year (RCP, 2016), which is also comparable to the wider economic cost of obesity of up to £27 billion p.a. (Morgan and Dent, 2010). More widely, the damage costs reported here were broadly consistent with estimates reported in a recent WHO study, which estimated the cost of disease and the premature deaths associated with a wider set of air pollutants (incl. PM) in the UK at around $83bn (£54bn) (Vidal, 2016; WHO, 2016). Note this includes all economic sectors and modes of transport, so is expected to be higher.

The results of the retrospective diesel 'purchase penalty' suggest a trade-off between a large *decrease* in local air pollutants against a modest *increase* in climate change pollutants. This can be explained by the significant fuel switching away from diesels in the UK car fleet during the 2009–2015 modelling period. The relative size of the effects was in line with other modelling exercises looking at CO_2 and air quality effects of policy (e.g. Leinert et al., 2013).

4.2. Key results: future policy

The finding that a diesel purchase tax is unlikely to transform the car market without considerable supply side and tax incentive measures promoting ULEVs (scenario DPT_EV) contributes to the debate on what policy options and industry investments are required to meet air quality and climate mitigation goals. While scrappage schemes can be effective in reducing emissions (CEMT, 1999; Kagawa et al., 2013), they have issues around reliance on increasingly scarce public funds, are potentially regressive (benefitting the rich more than the poor), and have potential rebound effects (Brand et al., 2013; Vaughan, 2014). A dynamic and revenue neutral 'feebate' system could be the better option in the medium term, as has been shown in a number of studies (BenDor and Ford, 2006; Brand et al., 2013). Furthermore, a purchase/scrappage tax should not counteract any CO_2-graded road tax regime that typically favours diesel cars due to lower CO_2 ratings (Leinert et al., 2013). One solution would be to disaggregate CO_2-graded taxation levels further by fuel type, as is currently the case for new company cars in the UK through differential BIK rates (HM Treasury, 2015).

To achieve higher and increasing emissions savings (up to 55% less NO_X and by 2050), 'co-benefits' (CO_2 *and* NO_X emissions reductions) and avoided damage costs beyond 2025 additional market changes, industry push, infrastructure investment and policy pull would be required. The marked transition to plug-in vehicles from the mid 2020s onwards explored in DPT_EV can be explained by the underlying transformational change in a number of areas beyond purchase price policy. First, DPT_EV implied that EV availability would increase following existing trends, meaning they will be widely available in all vehicle segments and by all major brands by 2030 (in the REF' baseline and DPT policy scenario, vehicle supply stays constant at 2015 levels, implying perceived supply penalties). Significant investment and repositioning by the major manufactures would be required, potentially driven by increasingly stringent new car CO_2 regulation after 2020 that eventually can only be met by ULEVs (Berggren and Magnusson, 2012). Second, consumer awareness and acceptance were assumed to increase significantly, with a steep increase in the 2020s (simulated by an S-curve) leading to 95% of potential buyers being aware of ULEVs and their incentives by 2030, and 100% by 2040. To achieve the critical mass for acceptance and awareness would involve require promotional campaigns, large field trials, dedicated car clubs and the 'neighbour' effect to diffuse widely and even convince the 'Resistors'. Third, the scenario further assumed investment in the next 15 years in high levels of overnight (mainly off-street) charging complemented by a national network of about 2000 rapid charging points for day charging to increase the market base for plug-in vehicles (in particular for the fleet segment) and provide national coverage by 2030. This effectively meant that by 2030 74% of private buyers (compared to 70% in REF'/DPT) and 80% of fleet buyers (compared to 40% in REF'/DPT) would have 'certainty of access' to charging. The investment needed would be in the tens of millions of GBP. Fourth, with a growing fast charging network happening over time the *perceived* EV charging times were decreasing with increasing BEV power rates (assumed to increase rapidly from 3 kW in 2015–7 kW in 2020 and then to 50 kW; for PHEV, this maxed out in 2020 at 7 kW). Last, in order to mitigate the purchase price premium of ULEVs the scenario assumed continued and improved equivalent value support for ULEVs for both private and company/fleet buyers, through capital incentives and continuation of the CO_2-graded VED that incentivizes ULEV uptake. The plug-in car-grant was recently extended to 2019 (instead of stopped after 2017) at the current rate of £5000, then reduced by half to 2024 (no grant from 2025 onwards). In addition, the company car tax regime was revised so

that cars emitting 50gCO_2/km or less (effectively BEV and PHEV) see the 9% Benefit-in-Kind (BIK) rate (as opposed to 13–16% as currently planned) (HM Treasury, 2015).

The results contribute to the growing body of evidence that while the health and environmental benefits related to fuel switching can be significant, the pace and scale of achieving those benefits is somewhat uncertain (Åström et al., 2013; van der Zwaan et al., 2013), particularly in the UK context where the projected deep decarbonisation of the electricity system over the longer term may prove difficult to achieve (Buekers et al., 2014). However, lower carbon content of future road electricity is the key component that drives the carbon reductions in DPT_EV. While the UK Government does not expect London and other AQ 'hot-spots' to meet legal pollution levels until at least 2025 (DEFRA, 2015a), ambitious taxation policy and further investment in electrified mobility will play important roles in meeting those targets in the medium term. However, this result cannot easily be translated to other countries which rely more on higher carbon (coal fired) power stations that can offset the life cycle carbon and health benefits of replacing diesel ICV with plug-in cars (Baptista et al., 2012).

Finally, fuel tax remains an important policy instrument (Montag, 2015) and source of government revenue (HM Treasury, 2015). While the UK already taxes diesel and gasoline at the same rate per litre, diesel is taxed 10% less per unit of energy (TandE, 2015a). Electricity is only taxed through VAT (currently 20% for road transport). This suggests there may be a case for revising the fuel taxation regime taking into account energy, CO_2 and air quality impacts – not just those associated with NO_X but also PM. In the longer run, the reductions in fuel duty revenues in *all* future scenarios can be explained by the take-up and use of more fuel efficient cars and, in the DPT_EV case, the zero duty on electricity as a road transport fuel. The latter issue has been recognised by the UK Government and other countries around the world – and it is expected that once plug-in vehicles make up significant market shares, electricity as a transport fuel will have to be taxed accordingly, with expected rebound effects on take up rates. However, as shown in a recent study for the UK (Brand et al., 2013), a fuel duty on electricity of 5 pence per kWh (roughly the gasoline-equivalent to the current duty rate for gasoline) would show relatively small reductions in plug-in vehicle uptake – reflecting the comparative energy efficiency advantage of electric drivetrains.

4.3. Outlook and future work

The approach used for this study contributes to the growing consensus that regulation and emissions budgeting based on tailpipe emissions is increasingly no longer fit for purpose and should be changed to be based on well-to-wheel, and ultimately life cycle, emissions (IEA, 2013). Currently the average fuel life cycle greenhouse gas (GHG) saving for a BEV over its full life has been estimated at about 50% under UK conditions – that is, with the current mix of grid electricity generation (Kay et al., 2013). This could increase to 75% in 2020 and to 83% by 2030 with the anticipated decarbonisation of grid electricity. Also, vehicle life cycle emissions (from manufacture, maintenance and scrappage) add significantly to emissions from vehicle use (IEA, 2013; Lane, 2006; MacLean and Lave, 2003) and can be significantly higher for BEV and PHEV than for ICV (Baptista et al., 2012; Kay et al., 2013).

Further work is required in exploring sensitivities around 'real-world' vehicle emissions factors of other pollutants affecting human health, most notably PM and hydrocarbons. While this paper focused on Dieselgate and related NO_X pollution and standards it is important to note that the inclusion in the damage cost calculation of other pollutants, notably PM, may change the damage cost values. Since total multi-pollutant valuations were likely to increase the totals, the figures reported in this study could be considered on the conservative side. Further work could also investigate the acceptance of various vehicle propulsion systems by a wider set of the heterogeneous fleet/company market actors. This could be achieved by employing Monte Carlo analysis, which can help analyse the propagation of multiple uncertainties in an integrated transport-energy-environment modelling system such as UKTCM (Int Panis et al., 2004).

4.4. Final thoughts

The policy and industry response in the aftermath of the 'Dieselgate' affair is in full swing. However, there are concerns in Europe whether more realistic 'real world' emissions test cycles will be approved and implemented anytime soon, and that the European Commission's car emissions testing may not have 'the muscle like US watchdog' (Stupp, 2016). Some of the major diesel car manufacturers have agreed to cooperate on real-world emissions testing and reductions, including Peugeot Citroen (TandE, 2015b) and Renault (AFP, 2016). The regulatory response should go hand in hand with further development of technological solutions to meet NO_X standards. These have been available for some time, including cooled exhaust gas recirculation, lean NO_X traps or selective catalytic reduction with ammonia (Bertelsen, 2001; Faiz et al., 1996; Sanchez et al., 2012). Manufacturers are usually chosing the NOx aftertreatment technology based on a combination of cost, reliability, fuel economy, and consumer acceptance.

By assessing the potential impact of different policy approaches and consumer responses to the 'de-dieselization' (Leinert et al., 2013) of cars, this study contributes to the growing consensus (Barrett et al., 2015; Carrington, 2016; Walton et al., 2015; Woodcock et al., 2009) that future policy may have to go the extra mile (pun not intended) by promoting additional market changes, industry push, infrastructure investment and policy pull in order to achieve the emissions savings, 'co-benefits' and avoided damage costs of a range of pollutants required to meet climate, air quality and health damage goals. Given the UK's strategic commitments to meeting its stringent climate objectives and realisation that this is likely to be achieved by a pathway similar to DPT_EV (CCC, 2015a), NO_X and other air quality pollutant emissions may be significantly reduced providing significant 'co-benefits'.

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Appendix A. Supplementary material

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Intergovernmental Relations and Clean-Air Policy in Southern California

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In 1989, California adopted a bold and comprehensive Air Quality Management Plan (AQMP) to bring southern California into compliance with federal air-quality standards by 2007. California's effort to control air pollution, as outlined in the AQMP, significantly influenced the formulation of the 1990 federal Clean Air Act. This article analyzes the nature of this influence as well as the way the new federal legislation bolsters specific provisions of the AQMP. Also examined is whether the AQMP and the Clean Air Act are likely to bring southern California into compliance with federal air-quality standards.

Although the nation's air quality has generally improved since 1970, certain regions of the country are still in violation of federal air-quality standards. In southern California, for example, initial gains made by the adoption of fairly stringent emission control laws have been offset by continuous population and industrial growth.[1] In fact, as of June 1991, California still did not have a state implementation plan (SIP) approved by the U.S. Environmental Protection Agency (EPA). In the past, federal officials have threatened to cut off funds for California highway construction and transportation and to levy other penalties if southern California did not come into compliance with federal clean-air standards.

In 1989, California adopted a comprehensive Air Quality Management Plan (AQMP) to bring southern California into compliance with federal air-quality standards by 2007.[2] Development of the AQMP was characterized by an impressive amount of intergovernmental cooperation between many local, regional, and state government units. The plan is the most far-reaching air-pollution control program in the country, and it significantly influenced the development of the federal Clean Air Act of 1990.

AUTHORS' NOTE: We would like to thank Larry Berg, a member of the South Coast Air Quality Management District Board, for providing valuable information on this topic. The perspectives expressed in this article are solely those of the authors.

[1]Sheldon Kamieniecki, Matthew A. Cahn, and Eugene R. Goss, "Western Governments and Environmental Policy," *Politics and Public Policy in the Contemporary American West*, ed. Clive S. Thomas (Albuquerque: University of New Mexico Press, 1991), pp. 479-497.

[2]South Coast Air Quality Management District, *Air Quality Management Plan: South Coast Air Basin* (El Monte, Cal.: SCAQMD, 1989).

INTERGOVERNMENTAL RELATIONS AND CLEAN-AIR POLICY

The shape of intergovernmental relations with respect to air-pollution policy has changed dramatically since the 1960s.[3] Federal air-pollution policy in the 1950s and 1960s was not coercive, and there was little intergovernmental cooperation in addressing the problem. Only a handful of states and localities had adopted air-pollution standards, and even fewer were enforcing them.

After failing at previous attempts to enact legislation to improve the nation's air quality, the Congress enacted the Clean Air Act of 1970.[4] This law ordered the newly created EPA to set national air-quality standards and certain emission limits. State and local governments, as well as industry, complained to the Congress that the new EPA standards and deadlines were unreasonable, and that they were being excluded from the policymaking process. The Clean Air Act Amendments of 1977 therefore attempted to establish a strong federal-state partnership by permitting a larger role for states in classifying areas for protection of clean air and providing flexibility to states in implementation.

Partial Preemption and Primacy

Environmental laws enacted in the 1970s also attempted to defuse hostility aroused by total federal preemption of state powers by adopting an approach that involves partial preemption.[5] As Patricia Crotty explains, "Under partial preemption, the federal government returns program responsibility to the states but retains the ultimate authority to decide on the acceptability of the states' actions."[6] States are permitted leeway to develop and implement their own pollution-control programs, but these programs must meet federal minimum standards and goals.

The Clean Air Act of 1970 and its 1977 amendments contain a unique partial preemption scheme, which environmental regulatory officials refer to as "primacy." Crotty argues that the federal government attempts to coopt states into implementing the provisions of certain environmental laws by offering generous grant awards. Primacy permits a state to apply for primary enforcement responsibility under the Clean Air Act. In order to be granted this power by EPA, state air-pollution control laws must be at least as stringent as federal law. EPA must enforce federal clean-air standards within states that elect not to apply for primacy. If a state is not in compliance with minimum federal air-quality standards, EPA can revoke its grant of primacy. Although California has accepted oversight responsibility for implementing the Clean Air Act within its borders, it has not been able to develop an implementation plan acceptable to EPA.

[3]Henry C. Kenski and Helen M. Ingram, "The Reagan Administration and Environmental Regulation: The Constraint of the Political Market," *Controversies in Environmental Policy*, eds. Sheldon Kamieniecki, Robert O'Brien, and Michael Clarke (Albany: State University of New York Press, 1986), pp. 275-298.

[4]Ibid.

[5]Patricia M. Crotty, "The New Federalism Game: Primacy Implementation of Environmental Policy," *Publius: The Journal of Federalism* 17 (Spring 1987): 53-67.

[6]Ibid., 54.

Reagan's New Federalism

During the 1980s, primary fiscal responsibility for implementing clean-air policy and other environmental programs was transferred from the federal government to state and local governments. New Federalism, as practiced by the Reagan administration, called for state and local governments to assume from the federal government many of the financial costs for protecting the environment. Thus, there was a substantial reduction in federal grant funds allotted to the states for air-pollution control activities and for other efforts to protect the environment.[7] Furthermore, an overarching concern for economic growth on the part of the Reagan administration thwarted efforts by environmental groups and members of Congress to enact legislation to reduce acid precipitation and enhance air quality. The Bush administration was more willing to negotiate on new clean-air legislation, eventually leading to the passage of the 1990 Clean Air Act Amendments.[8]

As Charles Davis and James Lester explain, advocates of Reagan's New Federalism maintained that the states, with their improved institutional capacities, were now in a position to take on greater responsibilities.[9] It would be up to state and local governments to decide which programs they wanted to retain and which ones they wanted to drop. Recognizing this, the public would become actively involved in the policymaking process.[10] In theory, public pressure would force state policymakers to make decisions reflecting local policy preferences, making it easier to shape policies to fit local or regional needs. Policy implementation would be smoother as a result.

Opponents of the New Federalism, however, contended that the Reagan administration shifted responsibilities to the states, at least in the environmental area, as a way to eliminate some programs.[11] This would most likely occur in states where polluting industries were powerful and exerted considerable influence over state elected officials. Moreover, opponents argued that states vary significantly in expertise and resources, and that certain states would be unable to assume responsibility for complex and expensive environmental programs. Some states would have no choice but to cut back or eliminate important pollution-control programs.[12]

Perhaps the major benefit of New Federalism is the extent to which it has

[7]Steven A. Cohen, "EPA: A Qualified Success," *Controversies in Environmental Policy*, eds. Sheldon Kamieniecki, Robert O'Brien, and Michael Clarke (Albany: State University of New York Press, 1986), pp. 174-195.

[8]Of course, the replacement of Robert Byrd (West Virginia) by George Mitchell (Maine) as the majority leader of the Democratic party in the Senate also made it easier to enact new clean-air legislation.

[9]Charles E. Davis and James P. Lester, "Federalism and Environmental Policy," *Environmental Politics and Policy: Theories and Evidence*, ed. James P. Lester (Durham, N.C.: Duke University Press, 1989), pp. 57-84. In addition, see James P. Lester, "A New Federalism? Environmental Policy in the States," *Environmental Policy in the 1990s: Toward a New Agenda*, eds. Norman J. Vig and Michael E. Kraft (Washington, D.C.: Congressional Quarterly Press, 1990), pp. 59-79.

[10]Daniel J. Elazar, *American Federalism: A View from the States* (3rd ed.; New York: Harper and Row, 1984).

[11]J. Clarence Davies, "Environmental Institutions and the Reagan Administration," *Environmental Policy in the 1980s: Reagan's New Agenda*, eds. Norman J. Vig and Michael E. Kraft (Washington, D.C.: Congressional Quarterly Press, 1984), pp. 143-160.

[12]Richard P. Nathan et al., *Reagan and the States* (Princeton, N.J.: Princeton University Press, 1987).

encouraged constructive policy innovation by many states. Citing data collected by the Council of State Governments since 1976, Lester reports that "the total number of innovations in the states increased dramatically during the 1980s" and that "the quality of the innovations improved as well."[13] One of the innovative programs Lester highlights is the AQMP in California. Prior to examining the individual components of the plan, the next section briefly discusses the air-pollution problem in southern California.

AIR QUALITY IN SOUTHERN CALIFORNIA

Despite recent improvements in air quality, the South Coast Air Basin in southern California, which includes Los Angeles, Orange, Riverside, and San Bernardino counties, has the highest air-pollution levels in the United States.[14] A combination of burning fossil fuels in power plants, heavy reliance on automobiles and other motorized vehicles for transportation, and natural mountain barriers is primarily responsible for the poor air quality in the region. Lead, sulfur dioxide, carbon monoxide, nitrogen oxides, and ozone are "cooked" by the sun to form a photochemical smog. The smog hurts the development of children's lungs; causes severe eye irritation, headaches, and respiratory problems in adults; kills plants, trees, and other life forms; and damages property. Long-term health effects, such as emphysema, are also thought to be associated with constant exposure to smog. Overall, the negative effects of air pollution cost the state and its residents several billion dollars each year.

Although California has enacted strict automobile-emission requirements and taken other actions since 1970, air pollution remains the most serious environmental problem faced by the state, and especially southern California. Based on data collected by the South Coast Air Quality Management District (SCAQMD), the regional state agency in charge of air-pollution policy in southern California, three of four major pollutants—ozone, carbon monoxide, and particulate matter—exceed federal standards significantly and are about three times worse than any other region in the state.[15] Ozone concentrations, for example, are nearly three times the federal standard, carbon monoxide is slightly more than two times the federal standard, and particulate matter is slightly less than two times the federal standard. Concentrations of nitrogen dioxide, the fourth major pollutant, are better, exceeding the federal standard by only 2 percent. These data, coupled with the known effects of air pollution on property, public health, and the environment, reveal the severity of the problem. Although other parts of California also have polluted air, the air quality is so poor in southern California that any overall state plan must focus primarily on ways to improve air quality in this region.

[13]Lester, "A New Federalism?" p. 62.
[14]SCAQMD, *Air Quality Management Plan.*
[15]Ibid., Chap. 1.

INTERGOVERNMENTAL COOPERATION IN THE DEVELOPMENT OF THE AQMP

The extent of the region's air-pollution problem was recognized as early as 1946 when Los Angeles County established the nation's first air-pollution control district. The California legislature, in the mid-1950s, created the first agency to monitor and control motor-vehicle emissions. By 1970, countywide air-pollution districts were required throughout the state. As a consequence of both federal and state mandates, SCAQMD was created in 1977, and presently includes a 13,350 square-mile area of Los Angeles, Riverside, and Orange counties, and the non-desert portion of San Bernardino County. SCAQMD played a key role in the formulation of the AQMP.

Several major federal and state laws led to the eventual development of the AQMP. The federal Clean Air Act of 1970 and the Clean Air Act Amendments of 1977 form the legal foundation of the pollution-control effort.[16] The South Coast Air Basin was one of 247 "air quality control regions" created by the 1970 Clean Air Act. The timetable for developing SIPs and meeting federal air-quality standards was originally 1975, but this deadline was extended to 1982 by the 1977 amendments, and extended even further, to 1987, for ozone and carbon monoxide. As already mentioned, southern California has not met these deadlines. In addition, the Lewis Air Quality Act of 1976, adopted by the California legislature as a response to the federal Clean Air Act, mandated the formulation of the AQMP and required that it be consistent with federal clean-air standards. It also laid out the bureaucratic procedures by which the AQMP was to be reexamined every two years and amended as necessary. Finally, the California Clean Air Act of 1988 outlined the planning requirements under which SCAQMD was expected to attain federal and state air-quality standards, and it set 31 December 1990 as the date for the district to prepare a plan for meeting these standards.

Integration of federal and state air-quality standards under a single plan requires the cooperation and approval of four major regional, state, and federal agencies. The AQMP was drafted jointly by SCAQMD, the Southern California Association of Governments (SCAG), and the state Air Resources Board (ARB).[17] SCAQMD, however, was the primary agency for developing the standards. The agency mainly regulates "direct" pollution sources, such as oil refineries and power plants, and "indirect" sources, such as regional shopping centers that may not pollute by themselves but attract motor vehicles that do. SCAQMD is governed by a twelve-member board comprised of nine elected county supervisors and city council members from within the district. It also includes three citizen appointees, one each appointed by the governor, the speaker of the state Assembly, and the state Senate

[16]Walter A. Rosenbaum, *Environmental Politics and Policy* (2nd ed.; Washington, D.C.: Congressional Quarterly Press, 1991), Chap. 6 contains a good discussion of the 1970 Clean Air Act. For a summary of the 1977 Clean Air Act Amendments, see James R. Wagner, "Clean Air Bill Extends Deadlines," *Congressional Quarterly*, 6 August 1977, pp. 1629-1632.

[17]SCAQMD, *Air Quality Management Plan.*

Rules Committee.[18] As one would imagine, the diverse political structure of SCAQMD often leads to considerable infighting among its members. SCAG played a major role in researching and preparing the AQMP, and the agency was responsible for drafting the transportation, growth management, and land-use elements of the plan. It is governed by a nineteen-member executive committee composed entirely of elected county and city officials from southern California. ARB's primary statewide responsibility is controlling motor-vehicle emissions. It was mainly in charge of developing the mobile-source control measures for the AQMP. ARB was created in 1967 and is composed of nine part-time members who are appointed by the governor.

The plan took approximately five years to develop and was the product of dozens of local workshops and presentations, ten public hearings, and ten months of public comment.[19] In general, more than fifty cities (including Los Angeles) and various environmental and community groups participated in the formulation and adoption of the plan, while chambers of commerce, developers, and industrial groups opposed most of the stringent measures. A number of cities in Orange County voiced reservations about certain aspects of the plan. Automobile, petro-chemical, and gasoline companies tended to be among the strongest opponents of the AQMP.

The AQMP took effect following approval of the plan by SCAQMD, SCAG, and ARB. At the same time, ARB submitted most of the plan (specifically those measures addressing air-quality standards required by the federal Clean Air Act) to EPA for approval as a revised SIP. Since then, a federal court has ruled that SCAQMD and the state should be given more time by EPA to comply with federal standards, despite the addition of new regulations in the 1990 Clean Air Act Amendments. At some point, however, EPA must rule on whether the AQMP, if fully implemented, will indeed bring the South Coast Air Basin in compliance with federal air-quality standards.

COMPONENTS OF THE AQMP

The AQMP targets the most serious pollutants, and contains detailed strategies for lowering the concentration of these pollutants. In 1991, SCAQMD postponed its target date for meeting federal air-quality standards by three years (i.e., from 2007 to 2010). The new deadlines for lowering the region's four major emissions are: 31 December 2000 for both nitrogen dioxide and carbon monoxide, and 31 December 2010 for both ozone and particulate matter. To achieve these objectives, control measures were placed into a three-step timetable based on "their readiness for implementation" and on the stringency required by the application of the controls.[20]

[18]For a discussion of the authority and structure of SCAQMD, SCAG, and ARB, see League of Women Voters of California, *A Guide to California Government* (San Francisco: League of Women Voters of California, 1981).

[19]See SCAQMD, *Air Quality Management Plan*, Executive Summary and Chap. 1.

[20]Ibid.

Tier I Control Measures

Tier I controls are those that can be adopted in the short term using current technology and, in most cases, with existing legal authority and management practices.[21] There are more than 130 control measures included in Tier I. All are expected to be adopted by the appropriate government agencies by the end of 1993. A number of measures were in place by the end of 1990. This first phase of the plan is largely action-oriented and applies mainly to stationary rather than to mobile sources of pollution.

Included in Tier I, for example, are controls on the production, refining, and distribution of petroleum products; the use of solvents and coatings; industrial and commercial processes involving, for example, boilers and internal combustion engines; and residential equipment and public services, such as furnaces and wastewater treatment plants. Transportation, land-use, and energy conservation controls are also included in Tier I to the extent that current technology is available to achieve emission-reduction goals. Among the specific measures included in this stage of the plan are a ban on the use of lighter fluid for barbecue grills, a requirement that restaurants that use charcoal broilers install special vents to reduce emissions, and a ban on the use of gasoline engines on lawn mowers. In order to reduce traffic and automobile exhaust pollution, free parking and "drive-thru" windows at banks and fast-food restaurants will be virtually eliminated.[22]

SCAQMD is in the process of creating an emissions permits trading program to replace some of its smog control regulations for stationary sources (e.g., power plants). Numerous details must be worked out, however, before such a market approach to controlling air pollution can be fully implemented. In 1991 alone, the implementation of Tier I provisions cost nearly $5 billion. Quantifiable benefits of this segment of the plan, however, were more than $6 billion.[23]

Tier II Control Measures

Tier II controls are mostly extensions, or more stringent applications, of Tier I controls. They include "on the horizon" technologies that can reasonably be expected to be developed in the short term. Immediate research and application of improved technologies are expected to allow Tier II controls to be in place by the year 2000. Control measures in this second phase include, for example: research and development in the areas of low-emitting fuel combustion technology; improved energy supply and distribution systems; rail transportation infrastructure; low-emission vehicles; and reformulation of solvents and paints.

In contrast to Tier I, Tier II more closely resembles a medium-range research and development work plan rather than a short-term action plan. Moreover, it places greater emphasis on mobile transportation sources than does Tier I. Tier II also identifies the actions required to ensure that necessary technological improvements occur according to the scheduled timetable.

[21]Ibid., Chaps. 4 and 6.

[22]Lester, "A New Federalism?" p. 62.

[23]South Coast Air Quality Management District, *Socio-Economic Report for 1991 Air Quality Management Plan* (El Monte, Cal.: SCAQMD, 1991), pp. ES2-ES5.

Tier III Control Measures

Tier III programs involve major technological breakthroughs that are expected to take place over the next two decades. The necessary advances in technology will require a vigorous commitment to research and development within the public and private sectors. SCAQMD, SCAG, ARB, and EPA are expected both to direct and to monitor research and development activities. Tier III presently has no specific measures in place, but programs are most likely to be directed toward further reducing emissions from motor vehicles and from paints and solvents.[24] This will be accomplished through continued improvements in fuel cells, superconductors, solar cells, vehicle emissions, and water-based solvents and coatings, and by eliminating certain coating processes. The projected cost of implementing both Tier II and Tier III will be about $2.3 billion. The estimated health benefits alone, however, will be approximately $9 billion.[25]

THE 1990 CLEAN AIR ACT AMENDMENTS

One year after California adopted its AQMP, the Congress passed the federal Clean Air Act Amendments. This 1990 legislation represents the first significant change in the Clean Air Act in thirteen years. There is good reason to believe that California's air-pollution control effort helped structure the new law, and that the Congress may have intentionally avoided undermining certain provisions of California's AQMP.

How California Influenced Federal Law

There are three major areas in which California's air-pollution control effort directly affected provisions of the 1990 Clean Air Act: alternative fuels, emission-control standards, and ride-sharing. Perhaps most significantly, the emphasis placed on switching to cleaner burning fuels in the AQMP was incorporated into the new federal law. Much of the air pollution control debate in California, and then later in the Congress, centered around ways to lower ozone levels. Ozone is a prime ingredient of smog, and it is produced by the combination of hydrocarbons and nitrogen oxides in the presence of sunlight and heat. Controlling hydrocarbon emissions is one way to decrease ozone concentrations. Oil and gasoline companies strongly opposed a focus on reducing hydrocarbon emissions as a method to lower ozone concentrations, however, because of the difficulty of measuring hydrocarbon emissions precisely. Instead, attention was turned to lowering emissions of nitrogen oxides. These pollutants are easier to measure accurately, and their presence varies directly with ozone.

This paved the way for agreement among the major parties to begin deemphasizing the use of gasoline in automobiles so as to place greater reliance on cleaner burning fuels, such as electricity, ethanol, methanol, compressed natural gas, and other sources. At the same time, California had also adopted strict emission-control requirements for stationary sources that would decrease the burning of oil and coal

[24]SCAQMD, *Air Quality Management Plan*, pp. viii-ix.
[25]SCAQMD, *Socio-Economic Report*, pp. ES2-ES5.

and that would increase the use of natural gas as a primary fuel. This, too, would help diminish ozone and smog. Following California's lead again, similar requirements were included in the federal legislation. These requirements should help improve air quality in regions of the country that have high concentrations of ozone. Controls on hydrocarbon emissions were still included in state and federal clean-air policy, but not solely for the purpose of reducing ozone in the atmosphere.

The AQMP also contains provisions to discourage industries from using fossil-fuel internal-combustion engines and furnaces in their production and manufacturing processes. Similar to the impact that strict tailpipe-emission requirements for automobiles will have, new emission requirements for stationary sources will eventually force industry to use engines and furnaces powered by electricity or natural gas. In some cases, electric power plants will have to switch from burning fossil fuels to burning natural gas. Similar emission-control standards were incorporated in the Clean Air Act and will, therefore, have to be followed nationwide.

The final area in which California helped shape the 1990 federal law was ride-sharing. In California, private firms employing over 100 people must now encourage their employees to car pool by providing them information on possible participants in car pools or van pools. In many cases, those who drive to work alone must pay a higher parking fee, and those who ride-share are allowed to park in preferential spaces. Some large companies have even begun their own van pool service. Incentive-based ride-sharing programs have been quite successful in California. Following the recommendation of California air-pollution control officials, the Clean Air Act encourages the adoption of similar incentive-based measures in areas with severe ozone problems.

Much of the direct influence California had over the final components of the 1990 Clean Air Act is attributed to the work of James Lents, executive director of SCAQMD, Professor Larry Berg, a board member of SCAQMD, and other state and local air-pollution control officials who advised the Congress on clean-air policy. In particular, Leon Billings, a lobbyist for SCAQMD, helped educate federal lawmakers about California's extensive air-pollution control program. These individuals were successful in persuading the Congress that measures already adopted in California, if properly crafted, could also improve air quality in other regions of the country. In addition, air-pollution control officials from California feared that the Congress would adopt strategies and requirements that would seriously undermine implementation of the AQMP. A much weaker federal bill probably would have encouraged polluting industries to challenge more vigorously California's stringent standards, or move to another state altogether. Apparently, California was successful in persuading the Congress to enact legislation that generally reinforces the state's clean-air program.

How Federal Law Will Affect California

The 1990 Clean Air Act will, to some degree, facilitate implementation of California's AQMP over the next two decades. At the very least, polluting industries in California will not be able to relocate to another region to avoid complying with tough air-quality standards. In several instances, the new federal

legislation sustains certain requirements in the California plan.

The federal clean-air legislation, for example, bolsters state plans to require automobile manufacturers to introduce a new generation of vehicles that operate on electricity and cleaner burning fuels, such as methanol and ethanol.[26] Initially, in the face of intense lobbying by oil companies, ARB rejected a recommendation by its own staff to require service stations to meet sales quotas for alternative fuels. Instead, as part of the implementation of Tier I provisions of the AQMP, the board merely required service stations to make the fuels "available" to consumers. However, making cleaner-burning fuels available and pricing them competitively to meet mandated sales objectives are two different things. The ARB staff and environmentalists are concerned that unless oil companies are required to meet fuel sales quotas, the more costly alternative fuels may not be able to compete with gasoline in the early years when automobiles will be built to run on both fuels. During this time, oil companies will have to price the new fuels below cost in order to make them competitive with gasoline. The new legislation contains a sales mandate, although most oil-firm executives dispute this interpretation of the federal provision. This controversy may, therefore, have to be settled in the courts.

In addition, the 1990 clean-air law contains tough federal tailpipe-emission standards for conventional, gasoline-powered automobiles.[27] These tailpipe-emission standards primarily involve hydrocarbons and take effect in 1994. The same tailpipe-emission standards take effect a year earlier in California under Tier I of the AQMP. Nevertheless, at least 20 percent of all the automobiles that arrive in California are purchased in other states, and now these vehicles will have to comply with the same strict tailpipe-emission requirements for hydrocarbons by 1994. For pollutants other than hydrocarbons, such as nitrogen oxides, California requirements become law several years before the same requirements take effect nationwide.

Moreover, the 1990 Clean Air Act will reinforce California's effort, as reflected in the AQMP, to control acid precipitation.[28] Average rainfall is highly acidic in much of the eastern and midwestern United States and sections of southeastern Canada. Even in the West, where rainfall typically is less acidic, abnormally acidic rainfall does occur in certain areas. The most acidic fog on record occurred in the South Coast Air Basin and was more acidic than lemon juice.[29] An increase in acid deposition could cause rapid acidification in the mountainous portions of California, where a number of lakes have a very low buffering capacity. The new clean-air law calls for a reduction of ten million tons in annual sulfur-dioxide emissions as well as a reduction of two million tons in nitrogen-oxides emissions by the year 2000. Power plants operated by utilities will be targeted to achieve these reductions, particularly those in the East and Midwest that still burn high-sulfur coal. Under

[26]Larry B. Stammer, "Federal Rules Take a Back Seat," *Los Angeles Times*, 1 November 1990, p. A5.
[27]Ibid.
[28]Ibid.
[29]Environmental and Energy Study Institute, "Issue Paper: The 1990 Clean Air Act Amendments," Washington, D.C., March 1991, p. 1.

the federal law, utilities are allowed to trade pollution rights within strict limits, a process that should help reduce acid rain and improve air quality. As mentioned earlier, SCAQMD is considering adopting a similar program for southern California. With respect to all major pollutants, California has been given twenty years (i.e., by 2010) to comply with federal air-quality standards.

Despite these gains, the 1990 legislation falls short of several of the provisions already included in the AQMP.[30] The federal law, for example, requires a 15 percent improvement in air quality in the first six years, with 3 percent annual average reductions in pollutants thereafter. California requires a 15 percent improvement in only three years, with 5 percent annual reductions thereafter. Federal standards for reformulated gasoline take effect a year later than identical California standards. In particular, a provision in the federal law preempts state regulation of all but the largest off-road vehicles and engines, such as tractors and construction equipment, which account for 10 percent of California's air pollution. The Congress turned this regulatory responsibility over to EPA. EPA's enforcement efforts in this area have been mixed in the past, and California officials and environmentalists remain skeptical that this will change in the future. The state is also disadvantaged because it is prevented from controlling numerous federal facilities located within its borders and from regulating railroad locomotives. In addition, California requirements concerning automobile smog-equipment warranties and gasoline pumps at service stations are considerably tougher than those in the federal law.

Overall, it is fair to say that California's approach to controlling air pollution strongly shaped the contents of the federal law rather than the other way around. In assessing the impact of the 1990 Clean Air Act on the AQMP, James Lents observed that, "For the nation as a whole, it's a big step forward. I think states like New York and Texas can be happy with what they saw. But the problems are just so difficult here that the federal act needed to go a little further for California. . . . It's sort of a wash."[31]

CONCLUSION

The main goal of policymakers, of course, is to bring southern California into compliance with federal air-quality standards by 2010. In many ways, California is implementing an experimental program. If the AQMP is successful, other states, the nation, and perhaps other countries will follow suit.

In some ways, Reagan's New Federalism encouraged the development of innovative and constructive policies in certain states.[32] California's creative approaches to solving many of its environmental problems are one example. In turn, federal policymakers incorporated a few of California's regulatory strategies into the 1990 Clean Air Act. At the same time, care appears to have been taken by the Congress not to undermine the state's effort to control air pollution in the

[30]Stammer, "Federal Rules Take a Back Seat."
[31]Ibid., p. A5.
[32]Lester, "A New Federalism?"

drafting of the new federal clean-air legislation.

However, despite the best efforts of state and federal policymakers to bring California into compliance with federal air-quality standards, several factors threaten the successful implementation of the AQMP. First, a serious and real deficiency of the plan is that it does not contain specific controls on population growth and development. By the year 2010, the South Coast Air Basin's population of 11,294,000 is projected to increase by 37 percent, to 15,449,000.[33] Some of this population increase, moreover, will be the result of federal policies on immigration and refugee resettlement. Increases will also occur in the number of vehicles in use, the number of miles driven, and overall industrial growth. Thus, in some cases, gains made from the imposition of strict air-pollution controls will be offset by population growth. Continued population growth will not only make it much more difficult to improve air quality in the region, but it will also place greater stress on an already dwindling water supply and on the environment as a whole.

Second, the long-term success of the AQMP relies heavily on the uncertain development of technologies that can reduce emissions from mobile and stationary sources. There is no guarantee that enough incentive will be present to encourage the technical advances needed to meet federal air-quality goals, or even that the necessary scientific breakthroughs will occur during the specified time period (especially in Tier III). Perhaps for mainly political reasons, the more difficult decisions have been postponed for a number of years, with the hope that new technologies will allow policymakers to meet federal clean-air standards with minimum disruption to people's life-styles and to economic growth. Unless the state is willing to provide outright grants or substantial tax breaks for research and development by private firms, technological progress in controlling emissions is likely to be slow.

Finally, the size and complexity of the pollution problem is enormous, and the presence of wealthy and powerful polluting industries makes it difficult for regulators to adopt strong control measures. Hence, it is difficult to see how the AQMP will deliver what is promised in time to meet the air-quality deadlines established by the Congress. Environmentalists might argue that this is one of the hidden goals of Reagan's New Federalism.

Regardless of the effectiveness of the plan, two items should be instructive to students of federalism. One is the process by which California policymakers influenced federal legislation; the other is how the Congress appears to have avoided undercutting the state's policy effort. Analysis of this type of federal-state interaction can lead to improvements in theories of federalism and to the development of more effective public policies. State innovation in attempting to solve problems of national significance might prompt the Congress to track state policymaking efforts more systematically and to consult with state officials more closely. This would allow federal lawmakers to adopt tried and tested policies, an opportunity they seldom have.

[33]SCAQMD, *Air Quality Management Plan*, pp. 3-13.

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Place-Based Stressors Associated with Industry and Air Pollution

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Abstract

Exposure to air pollution and its sources is increasingly viewed as a psychosocial stress, however its nature is not understood. This article explores the role of the concept of place on risk perception and community stress within data collected from eight focus groups in Philadelphia, USA. Discussions focused on air pollution, a nearby oil refinery, health, and a proposal for air monitoring. We present a framework of place-based elements of risk perception that includes place identity, stigma and social control. Our findings indicate that air pollution contributes to physical and psychosocial conditions that act as community-level social stressors. Findings also suggest that programs which seek to change behaviors and gather or spread information on issues

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such as pollution and other environmental concerns will be challenged unless they directly address: 1) the public's identification with a place or industry, 2) immediate environmental stressors such as abandonment, waste and odors, and 3) public perceptions of lack of social control and fear of displacement.

Keywords

air pollution; place; stigma; psychosocial and community stress; oil refinery

INTRODUCTION

There is an established relationship between air pollution exposure and poor health, including cardiovascular and respiratory disease (Brunekreef and Holgate, 2002; Dockery et al., 1993; Pope et al., 2002). Living or working in close proximity to heavily trafficked roadways or heavy industry has been associated with asthma and respiratory infection (Brauer et al., 2007), lung cancer (Attfield et al., 2012), and low birth weight or pre-term birth (Lin et al., 2001; Yang et al., 2002). Such evidence has been used to inform regulatory strategies on an individual-chemical basis, such as via the United States' Clean Air Act.

There is increasing evidence that communities exposed to higher levels of air pollutants may also be more vulnerable to the effects of this exposure. Environmental hazards are often co-located with non-chemical social stressors such as poverty and violence. These stressors can influence health by triggering negative emotions (such as fear, anxiety or depression), which affect physiological processes such as endocrine and immune systems and increase risk of disease (Cohen et al., 2007). Social stressors have been shown to affect respiratory disease, asthma, cardiovascular disease, cancer, depression, and HIV/AIDS (Astell-Burt et al., 2013; Cohen et al., 2007).

Exposure (to air pollution and its sources) itself can also be interpreted as a psychosocial stress on individuals (Atari et al., 2011; Atari et al., 2013; Bickerstaff and Walker, 2001; Chen et al., 2008; Clougherty et al., 2007; Cutchin et al., 2008; Gee and Takeuchi, 2004; López-Navarro et al., 2013; Luginaah et al., 2010; Luginaah et al., 2002a; Luginaah et al., 2000, 2002b; Shankardass et al., 2009; Yang and Matthews, 2010). Likewise, perceptions of air pollution have been shown to effect disease-status (Gee and Takeuchi, 2004; Piro et al., 2008). Yet exposure and risk assessment tend to focus on single pollutants, exposure pathways and health outcomes, and neglect to characterize or incorporate stress (Sexton, 2012). Many argue that risk assessments and environmental health interventions should be informed by social perceptions and local knowledge regarding pollution and risk (Corburn, 2003; Luginaah et al., 2010).

Risk theory offers a framework by which to understand the socio-cultural nature of air pollution. According to risk theory, Western societies have become increasingly aware and concerned about "modern" technology-based environmental risks (Beck, 1992a; Giddens, 1991). Multiple authors have called for an expansion of this theory to include the 'spatial organization of risk' (Beck, 1992b; Bickerstaff and Simmons, 2009; Giddens, 1991; November, 2004), in which environment and culture, people and places ('context' and

'composition') are viewed as contingent rather than distinct and separate (Cupples, 2009; Macintyre et al., 2002). Place indicates the physical aspects of locations as well as the social and emotional meanings tied to them (Tuan, 1977), and is a meaningful concept for risk studies because it underscores the role of space in the formation of identities (Twigger-Ross and Uzzell, 1996), feelings of belonging, defining of social boundaries or conflicts, and in other emotional processes.

Multiple studies have identified concepts tied to place relating to stress or risk perception. Day (2006) adapted a place-based framework developed by Curtis (2004) to explore the air pollution perceptions. Prior to this work, studies of risk perception and stress relating to air pollution have addressed place-based concepts, but only implicitly. In this study we apply three concepts to analyze the role of place in risk perception: place identity, stigma and social control. Place identity refers to the role of an individual's physical surroundings in their self-identity (Proshansky et al., 1983). Wester-Herber (2004) suggested that place identity is related to risk perception; perceived risks to land and environments will necessarily threaten individuals' perception of self. Others have demonstrated ways that at-risk environments are incorporated in to individuals' identities (Atari et al., 2011; Luginaah et al., 2010). Related to place identity is the concept of displacement, which represents unwillful movement from a place, for example via gentrification, and disrupts well-being, community ties and attachments (Newman and Wyly, 2006).

Stigma is a second place-related concept related to risk perception (Wester-Herber, 2004). Negative images associated with places can affect individuals' perception of self. Multiple studies have found stigma to play an important role in stress associated with living in proximity to industrial facilities or pollution (Atari et al., 2011; Bush et al., 2001). In addition, we investigate the role of social control in risk perception. Social control represents structural social and political hierarchies, often enacted or reproduced in spaces and places (Lefebvre, 1991; Massey, 1993). In the context of environmental hazards, lack of power and agency can act as determinants of risk perception (Bickerstaff, 2004).

This study questions the role of place in risk perception and community stress within analysis of qualitative data collected from eight focus groups conducted with 47 residents of the Point Breeze and Grays Ferry neighborhoods of Philadelphia, USA. These neighborhoods are adjacent to the Philadelphia Refinery, one of the oldest operating urban refineries in the US. The study is preceded by announcements by local officials of plans to begin a local air monitoring effort. Based on our analyses, we present place-based elements of risk perceptions in low-resource communities adjacent to an oil refinery, including: (1) place identity, (2) stigma, and (3) social control. We begin with a description of the project area, collaboration driving this project, methods and results from the study. We then describe how findings can influence public outreach, health interventions and risk assessment.

BACKGROUND

The Philadelphia Refinery began operation in Southwest Philadelphia in 1866 (see Figure 1). Sunoco Inc. purchased this refinery in 1988, and the Carlyle Group obtained partial

ownership in 2012. It currently processes 330,000 barrels of crude oil each day for retail throughout the Northeast Atlantic region of the United States. Approximately 1,000 individuals are employed in refining processes.

This refinery is the largest source of air pollution, by pound, in the greater Philadelphia area. In 2012, the refinery reported 762,000 pounds of chemical releases, which was more than 70 times higher than any other nearby facility. This refinery and other industrial facilities in the U.S. are subject to regulations under the Clean Air Act regarding air toxic releases. According to the Toxics Release Inventory (TRI; a mandatory, self-reporting program affecting certain facilities), the Philadelphia Refinery ranked 23 out of 134 similar facilities in the U.S. for total on-site releases in 2012.

In addition, the refinery has been out of compliance with at least one regulatory requirement (e.g. operating requirements, maximum emission rates or quantities) despite 28 Notice of Violations and $740,000 in penalties since September of 2000.

There have been concerns about the unfair impact of heavy industrial activities, including oil refining, on nearby neighborhoods in the Philadelphia area. First, environmental hazards are more highly concentrated in communities bordering the Delaware River, which includes our study area (Sicotte, 2010). Second, the refinery is surrounded by vulnerable populations potentially exposed to physical and psychosocial stressors associated with poverty and the physical environment. According to the 2010 Census, of the 45,000 residents living in census tracts within 1.6 kilometers from the refinery (which includes the study area), 29% were white, 59% were black, 8% were Asian, and 4% were Hispanic or Latino. Thirty-two percent of residents live below the federal poverty level, 21% of residents age 25 and older have not graduated from high school and 41% have a high school diploma or equivalent (U.S. Bureau of the Census, 2009). Other studies document the presence and nature of stressors in Philadelphia neighborhoods, such as hazardous waste sites, traffic volume (Yang and Matthews, 2010), vacant properties and lots (Branas et al., 2011).

Third, health risks tend to be greater in areas with a higher percentage of non-white residents, and lower levels of education and income (Sicotte, 2010). The most recent National Air Toxics Assessment, conducted by the U.S. Environmental Protection Agency (U.S. EPA) and based solely on pollutant exposure, indicated high health risks in Philadelphia; an excess lifetime cancer risk of greater than one in a million from exposure to 12 different toxins, including benzene, formaldehyde, acetaldehyde, and arsenic compounds.

Multiple studies have documented compounding effects of air pollution exposure and stress on asthma (Chen et al., 2008; Clougherty et al., 2007; Gordian et al., 2005; Pittman et al., 2012; Shankardass et al., 2009). Residents in the study area suffer from high rates of asthma. The Asthma and Allergy Foundation of America ranked Philadelphia as having the fourth worst asthma rate in the country in 2013. The Philadelphia Health Management Corporation's 2012 Household Survey confirmed that residents of Philadelphia (24% of children; 19% of adults), and South/Southwest Philadelphia in particular (14% of children; 24% of adults), suffer from high rates of asthma compared to national averages (9% of children; 8% of adults) (Philadelphia Health Management Corporation, 2012).

Point Breeze and Grays Ferry are historically working-class neighborhoods. Both are located near to the central business district, major academic and health care-related employment centers in Philadelphia. Residents see rising real estate values, new construction and new residents moving in to the northern and eastern parts of the study area in particular. There has been a fight over neighborhood identity, symbolized by the re-naming of some areas of Point Breeze.

The South Philadelphia Air Toxics Community Engagement Project

This study is a product of a growing movement in the communities of Point Breeze and Grays Ferry to address air (in addition to water and soil) pollution concerns. This movement largely began with the formation of the Right to Know Committee provided in 1994 by former employees of the Defense Personnel Support Center in South Philadelphia. The Committee advocates and raises public awareness about environmental health issues through community-based research, community meetings and other outreach tools.

In part due to the Committee's advocacy, agencies have sought resources to document and address air pollution concerns in the area. In 2011, the U.S. EPA awarded the City of Philadelphia Public Health Department – Air Management Services (AMS) a two-year Community Air Toxics Monitoring Grant to purchase a multi-gas open-path air-monitoring system to sample for target compounds near the Philadelphia Refinery. These compounds included Benzene, Mercury, Naphthalene, which are known human carcinogens, and Ethyl Benzene and Styrene which is possibly carcinogenic to humans (World Health Organization International Agency for Research on Cancer, 2013). AMS began purchasing equipment and communicating with community organizations about their plans to record continuous real-time air toxic concentrations in 2012. The agency was interested in formulating a communication strategy that could be used after data collection began. Plans for the monitoring effort were shared during the focus group discussions.

U.S. EPA is also focusing resources on raising air toxics awareness in South Philadelphia. In 2012, U.S. EPA named Philadelphia as one of four sites for a Toxics Release Inventory Community Engagement Pilot Project. This project has resulted in a "Train-the-Trainer" session on EPA's MyRTK web-based search tool, and development of TRI factsheets for the area. This project also motivated questions about how to engage the local community on air toxics issues.

This study represents a collaboration between the Right to Know Committee and other community organizations such as South Philadelphia H.O.M.E.S., Diversified Community Services, Neighbors in Action, and Neighborhood Network Plus; agencies such as AMS and U.S. EPA Region III; and representatives from Drexel University and the University of Pennsylvania to raise environmental awareness, build capacity and reduce risk in the project area.

METHODS

The purpose of this research project was to qualitatively explore the thoughts, beliefs and perceptions of environment, pollution and risk in Point Breeze and Grays Ferry

neighborhoods, adjacent to the Philadelphia Refinery. We recruited adults above the age of 18 using snow-ball sampling and purposive sampling methods (Fred and Kerlinger, 1986). All recruitment and consent protocol were reviewed and approved by the Internal Review Board of the University of Pennsylvania, and co-approved by the IRB of Drexel University via an authorization agreement, and the U.S. EPA Human Health Subjects Research Review Official. Our main recruitment strategies were: announcements at community meetings, word-of-mouth to social networks of community contacts, notices in church bulletins, and flyer and email distribution to neighborhood businesses and organizations. Incentives included a meal and $10 gift card to a local supermarket, and childcare during the discussion session.

Focus group procedures

We held eight focus group discussions with a total of 47 residents of the Point Breeze and Grays Ferry neighborhoods (or those living in the zip codes of 19145 and 19146) between March 8 and May 28, 2013. We selected a focus group methodology, over interviews or surveys, to better support participants' discussing topics in their own terms (Denzin and Lincoln, 1994).

We held focus groups at three separate locations. The first five were held at Vare Recreation Center at the recommendation of our community partners. Vare is located at the border between Point Breeze and Grays Ferry, and is considered to be on "common ground". The remaining three groups were held with regularly-scheduled gatherings at two separate churches.

The number of participants in each focus group ranged from two to ten (mean = 6). Out of 47 participants, 39 were self-reported as African-American and seven as white (and one did not report race); one was Hispanic; 40 of our participants were female and seven were male. We had one participant under age 24, five participants between the ages of 24 and 54, and the remaining 41 participants were over the age of 54 (three did not report their age). One limitation of this study is that we were not able to successfully recruit representative numbers of men, youth or participants from other racial, ethnic, or language groups.

The two PIs (Kondo and Gross-Davis) each facilitated half of the discussions. At least three assistants also attended each group, operated video and audio recording equipment, assisted with access to food and beverages, distributed and collected consent forms, demographic surveys, maps and gift cards, and took notes. Consent forms provided details about the purpose, duration, location, compensation, benefits and risks associated with the study. It also detailed terms of confidentiality. All (two PIs and six assistants) attended a practice training sessions, and attended at least three focus groups in order to receive adequate training and experience with each facilitation task. Focus groups lasted 60 to 90 minutes and covered the following questions:

- What do you consider to be your neighborhood?
- What do like and dislike about your neighborhood?
- How does your neighborhood support/harm your health?

- Are you concerned about pollution in the neighborhood?
  - (If air pollution is not discussed) How about air pollution?
- What are the sources of pollution here?
  - (If the refinery is not discussed) What are your thoughts on the refinery?
- What are the main health issues in your neighborhood?
- Has a physician treated you or any member of your family for asthma?

We pilot-tested questions with community contacts prior to implementation. Note-takers recorded observations of participants prior, during and after the actual focus group session. Observations included side conversations, gestures, body language, facial expressions, and other things that might be considered meaningful. During the session, the lead note-taker used a chart to categorize the notes with coded letters corresponding to the participants' comments. The focus group sessions were audio- and video-recorded.

Data analysis

Within two weeks of each session, we transcribed each focus group discussion in entirety. We then used constant comparison analysis methodology (Barney and Strauss, 1967), a form of grounded theory research, to analyze the data. The research team reviewed all of the transcripts and developed a list of independent codes collaboratively in an open coding process. We then arranged small units in to broader themes (axial coding). The third author served as the primary coder, using QSR NVivo 10. The group met weekly to review and revise codes. We completed adding and revising new codes once theme-based saturation had occurred.

We then generated node reports (compilation of all quotes) and memos (summarizing and drawing connections between themes within each node). All authors reviewed and discussed these memos at team meetings. The major themes on which we report – residents' perceptions of the refinery, industry, air pollution, and environmental health through the lens of place – were derived from this iterative process of reports, memos and discussions.

RESULTS

Analyses of data collected from focus groups are arranged in three themes that emphasize the role of place in risk perceptions regarding an oil refinery.

Place Identity

Despite the fact that the study area is in the shadow of an oil refinery (most commonly referred to as "Sunoco"), participants did not voluntarily mention it, air pollution, or industry in five of the eight focus group discussions. Air quality, in a community adjacent to one of the oldest refineries in the country, was mentioned only 17 times across all focus groups.

Yet when prompted about air pollution and the refinery, the most common response was apathy. This response was motivated, in part, by the fact that the refinery had been there for

so long, and was just a fact of life. Many participants had lived in the area all their lives, and identified with the historic presence of the refinery. Long-time residents, or participants over the age of 65, shared stories about how the refinery had been a presence in their childhoods. One participant said that "I remember my father would drive through the back way, to take us out as kids."

While none of our participants, or their relations, had been employed at the refinery, they expressed being "used" to the refinery because of its historic presence. One participant said, "The refineries they have there…After a while you get used to it." Another participant replied, "Yeah, the refinery, the chemicals …You learn to live with it, become immune to it." Long-time residents also noted that technological advances had allowed the refinery to become less noticeable. One woman stated: "The refinery *used* to smell, black smoke *used* to come up" (emphasis added).

Another participant stated that smells from the refinery, and the sight of black smoke, are a part of living in this place. She likened these sights and smells to exposure to violence, such as the sound of gunshots:

> "When you live with this stuff daily, it becomes part of your environment and your life and you really don't think about it because it's there all the time. And when you said pollution, yeah we're inundated with it, but it's with us, it's like a natural thing. You breathe in the air, you don't really think about it until you said something…Yes, the refinery, it has pollution. There are times when something is amiss at that Sunoco place and you do smell something, or there's black smoke coming out of the stack. But you see it all the time and say 'Well, alright.' I mean just like gunshots, you hear them all the time, and just say 'Yeah, okay'."

Stigma

After initially expressing apathy, participants began to volunteer perceptions of pollution and its effect on their mental and physical health. Participants admitted being very aware of air pollution (which they attribute to the refinery and the interstate that bisects the community) through sights and smells. First, smoke or other visible emissions from smokestacks at the refinery are visual cues to pollution exposure. While emissions are less visible than they may have been 30 years prior, they still exist: "Sunoco. It's amazing what fumes that comes out of there. It reaches all the way down."

The presence of the refinery and the pollution and especially odors emitted from it was a source of stigma. In the third focus group, all participants agreed that South Philadelphia has a reputation for smelling of gas and oil: "You know about South Philadelphia, it's always smelled, you smell gas and diesel." One participant said that she became aware of the odors in South Philadelphia only after she moved away to another section of the city: "I moved up to North Philly when I first got married…and it dawned on me, I had gotten used to the smell, and North Philly doesn't smell the same as South Philly." Oil refining contributed to a negative reputation that reflected poorly on residents and their community.

A related, more visually and consciously present source of stigma (and stress) for residents was vacant properties and pervasive trash in their neighborhoods. Rather than air pollution, the most commonly cited environmental health concerns were trash or "dirty streets" and vacant lots, or physical disorder. Participants reported that1) residents drop trash on to sidewalks, streets and alleys, 2) there is a lack of public trash cans in the neighborhood, and 3) garbage collectors often spill trash and neglect to pick it up. One participant stated: "There's trash everywhere. You can't take two steps without, 'Dang, there's another bottle!'"

Social Control

Pervasive trash, persistent crime and other social issues, lack of educational and employment opportunities as well as air pollution exposure were associated with feelings of lack of control and neglect by institutions within the neighborhood. Some participants asked why their neighborhood had been singled-out as a place of neglect. For example, while waste management problems are present in other areas of the city, the lack of trash in the adjacent more affluent neighborhood called Center City increased awareness of the problem in the study area. One participant described this contrast: "In center city where [people with] money are moving in, if you walk down their block they have the $300 fine for littering. So there is no littering, the blocks are clean, people clean up the parks. I'm like 'If they have that there why can't we have it here?'"

Participants also associated unwilling exposure to air pollution and crumbling infrastructure with lack of social control. Discussions indicated that exposure to air pollution from nearby industry and the refinery contributed poor community health, including cancer and respiratory disease. Asthma and respiratory symptoms (such as bronchitis) among children and adult populations was the top health concern reported in focus groups. Participants linked the refinery, as well as cigarette smoke exposure, to asthma, for example: "I would say there's a direct correlation between that refinery and all these children with asthma." The next most-frequently mentioned health concern was cancer. They linked occupational air pollution exposure to respiratory disease and cancer in adult residents. One participant stated:

> "A lot of [older residents] have died with a respiratory [disease], even cancer. Because a lot of them worked at these refineries, and these electric companies, and in the sewers, and so forth…So a lot of the illnesses that a lot of our parents and grandparents suffered and died from was because of the refineries and where they worked."

One participant blamed neighborhood incidence of cancer, and cancer mortality, on air pollution: "That air that's around us caused my breast cancer, my girlfriend had it, my other girlfriend died from it."

Participants who live near the elevated rail line bisecting the neighborhood along 25th street (Figure 1) felt that the refinery placed them in imminent danger. These participants all reported that trains carry petroleum products, and that the railway is old, crumbling, and has no safety features; they feared that if a train derailed, the hazardous materials would spill on their houses and in their back yards. As one participant stated:

> "They are transferring a lot of oil and gas through the neighborhood. And I just fear, we recently seen what happens when a train goes through a community and derails in New Jersey. Tons and tons [of oil] goes through our neighborhood and we don't know exactly when an accident like that would happen and that concerns me."

While participants suspected negative influences from outside forces, they also expressed a sense of powerlessness or lack of efficacy to counter those influences. For example, one participant stated: "The city fumes and garbage and everything else, you get immune to it because there's nothing you can do about it. Our politicians aren't doing anything, the mayor's not doing anything. We can't move, we're stuck."

Social Control and Displacement—Air monitoring campaigns are often assumed to be welcome advances to knowledge among experts, environmental and public health officials, and communities. Instead, many participants reacted with suspicion to the news of the monitoring effort. This suspicion was related to feeling vulnerable to negative influences of outside forces including surrounding industry, the city administration and other institutions. In particular, we found that the refinery, and the proposal to study and thereby reduce pollution, triggered feelings of discrimination, fear of displacement, or lack of security in ownership and belonging in their place of residence.

A major theme emerging from conversations before, during and after focus groups was unequal distribution of power and resources. Most focus group discussions started with questions of WHO was conducting the focus group study and the City's air monitoring campaign, WHO were the funders, WHERE and to WHOM the resources were going, WHO was making decisions about how it was spent, and ultimately WHOSE interests were being served.

Air pollution for many participants is a symbol of discrimination, neglect, unfair burdening of some with risks, and unfair profit by others. The very existence of the focus group study, and of the city's air monitoring campaign, indicated to participants that someone was giving and receiving money on the basis of air pollution in their neighborhood, and that someone was not them or any other resident.

While intentions of improving air quality in neighborhood such as these are good, residents suspected that these "do-gooder" actions were only motivated by selfish interests on the part of those who already have resources – including the city and public officials, universities and researchers. As one participant bluntly stated: "We're suffering, and now you come in talk about money about the air, and you don't give a darn about us. Really you don't."

Some participants asked directly, why grant money was not being spent on real needs, like providing opportunities and education for children in the neighborhood: "I think that it's a sin and a disgrace that the city of Philadelphia received a grant for environmental and they have no concern about our children."

The topic of air pollution, and the study of it, triggered fear of displacement for participants as well. Participants feared that talking about air pollution, and sanctioning public resources

spent on its abatement, contributed to residents' risk of being priced out of their homes. One participant demanded, "I'd like to know why all of the sudden we're concerned about Point Breeze and Grays Ferry when this place [the refinery] has been here since 1800s?" Concern and talk about "air pollution" and "the environment" was only in the interests of those with more resources, i.e. predominantly white residents that are moving in to the neighborhood. "Since there's a new population that's going to be moving us out and coming in, now there's studies on housing, and now air pollution is a big problem in the neighborhood." In one participant's opinion, people and agencies who want to help should "get off the environmental thing and get into more of the bigger community [issues]," which facilitators understood to mean lack of resources for youth, violence and disordered physical environment.

DISCUSSION

Exposure and risk assessments traditionally neglect the role of psychosocial stressors in the exposure-disease pathway, and in the formulation of possibilities for scientific, programmatic or regulatory response. Risk theory offers guidance toward understanding social dimensions of environmental hazards. We contribute to others' work expanding this framework to incorporate place-based concepts of place identity, stigma and social control. While multiple studies explore the role of place in risk related to air pollution, understandings are generally "fragmented" (Day, 2006). Through exploration of community concerns regarding a refinery and an air monitoring proposal in South Philadelphia, we provide a framework of ways in which place influences air pollution-related stress and risk perception. This framework is one of few that focuses on air pollution and takes a 'relational' approach to place; treating context and composition not as binary, but as contingent and mutually related (Cummins et al., 2007; Macintyre et al., 2002).

This study offers an in-depth look using qualitative data in two neighborhoods in Philadelphia. Participants were not randomly selected and their statements should not be seen to represent community-wide sentiment. The framework developed in this paper is grounded in specific issues emerging from South Philadelphia communities in the shadow of a large petrochemical refinery. While the findings cannot be generalized to represent experiences in other communities, they can suggest important questions to investigate using other methods in similar areas. In addition, not all aspects of place are included in this analysis, for example those that cannot be detected by use of qualitative methods, though they are worthy of study.

However, this study does provide evidence of a relationship between stress, environmental exposures and disease. Few studies investigate the relationship between the perception of air pollution and disease outcomes (Gee and Takeuchi, 2004; Piro et al., 2008). We join others in calling for further research on "stress-intoxicant interactions" (Couch and Coles, 2011; McEwen and Tucker, 2011), which may assist in understanding and reducing health inequality.

Our analysis revealed that South Philadelphia residents are aware of the nearby urban refinery; their awareness is triggered by visual cues and aromas. Yet they "absence risk"

(Bickerstaff and Simmons, 2009) due to place identities, and to protect themselves from fear of disease and displacement, feelings of stigma and discrimination. While they feel powerless to change it, they also fear that any effort to reduce impacts would not be in their best interest. Our findings align with others who have found that feelings of (lack of) social control causes individuals to constantly feel in danger, excluded from public spaces, activities and resources (Brownlow, 2006; Sparks et al., 2001).

Findings suggest that programs or studies which seek to change behaviors and gather or spread information on issues such as pollution and other environmental concerns will be challenged unless they directly address: 1) the public's identification with a place or industry, 2) immediate environmental stressors such as abandonment, waste and odors, and 3) public perceptions of lack of social control and fear of displacement. This reflects prior studies which have found that targeted behavioral health interventions are largely unsuccessful when they do not address immediate environmental threats (Ory et al., 2002), lack of trust (Scammell et al., 2009), and otherwise incorporate local knowledge (Corburn, 2003). In this case as in others (Couch and Coles, 2011), the study process could exacerbate the physical and psychosocial health impacts on communities.

Study results suggest that it may be possible to reduce impacts of pollution through mitigation of other related social and physical stressors. For example, place-based programs to improve environments, such as cleaning and greening of vacant lots, improving housing (Branas et al., 2011; Branas and MacDonald, 2014) or solid waste management could reduce vulnerability to effects of air pollution exposure.

In addition, our findings suggest that efforts to monitor pollution and exposure levels, document environmental injustice, and organize action, must be sensitive to power dynamics and fears that go along with neighborhood research and improvement. A community-initiated or community-engaged method will be fundamental to either of these types of efforts, in which researchers help answer questions derived from the community. It is essential that collaborative efforts seek and provide funding for outreach and education with and among neighborhood residents.

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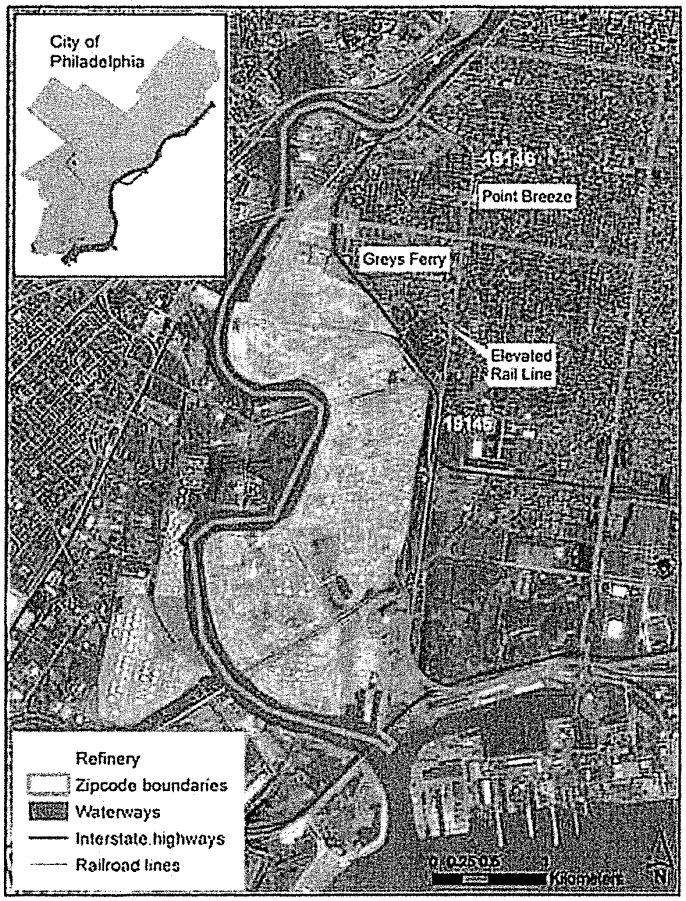

Figure 1.
Overview Map Showing Philadelphia Refinery and the Grays Ferry & Point Breeze Neighborhoods

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ENVIRONMENTAL HEALTH

RESEARCH Open Access

Traffic-related air pollution and obesity formation in children: a longitudinal, multilevel analysis

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Abstract

Background: Biologically plausible mechanisms link traffic-related air pollution to metabolic disorders and potentially to obesity. Here we sought to determine whether traffic density and traffic-related air pollution were positively associated with growth in body mass index (BMI = kg/m^2) in children aged 5–11 years.

Methods: Participants were drawn from a prospective cohort of children who lived in 13 communities across Southern California (N = 4550). Children were enrolled while attending kindergarten and first grade and followed for 4 years, with height and weight measured annually. Dispersion models were used to estimate exposure to traffic-related air pollution. Multilevel models were used to estimate and test traffic density and traffic pollution related to BMI growth. Data were collected between 2002–2010 and analyzed in 2011–12.

Results: Traffic pollution was positively associated with growth in BMI and was robust to adjustment for many confounders. The effect size in the adjusted model indicated about a 13.6% increase in annual BMI growth when comparing the lowest to the highest tenth percentile of air pollution exposure, which resulted in an increase of nearly 0.4 BMI units on attained BMI at age 10. Traffic density also had a positive association with BMI growth, but this effect was less robust in multivariate models.

Conclusions: Traffic pollution was positively associated with growth in BMI in children aged 5–11 years. Traffic pollution may be controlled via emission restrictions; changes in land use that promote jobs-housing balance and use of public transit and hence reduce vehicle miles traveled; promotion of zero emissions vehicles; transit and car-sharing programs; or by limiting high pollution traffic, such as diesel trucks, from residential areas or places where children play outdoors, such as schools and parks. These measures may have beneficial effects in terms of reduced obesity formation in children.

Keywords: Childhood obesity, Air pollution, Traffic, California

Introduction

Childhood obesity has emerged as a major public health problem in the United States and elsewhere. Since the 1970s rates of overweight and obesity have more than doubled in the U.S. from about 15% of youth aged 2–19 years who were considered overweight or obese, to 32% in 2003–2006 [1,2]. Although the trend toward increasing obesity in the U.S. appears to have abated over the past ten years [3], the existing high prevalence remains a concern. Similar patterns of increasing childhood obesity prevalence have been reported in several other countries [4]. The increased prevalence of overweight and obesity in children has serious ramifications for future trends of metabolic disorders and disease, cardiovascular and pulmonary disease, gastrointestinal conditions, skeletal problems, cancer incidence, mortality, and psychosocial disorders [5-7]. While genetic and metabolic susceptibilities exist, the rapid rise in obesity prevalence implicates environmental factors as contributors to obesity development in children [8].

Growing evidence links the built environment to physical activity, dietary intake, and obesity [9]. Previous research has examined the impacts of land use patterns such as "urban sprawl" [10], local land use mixtures

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[11], and accessibility of neighborhood features that either promote or undermine health (e.g., exercise facilities or fast food outlets) [12,13]. Much of the existing evidence comes from cross-sectional studies [14], raising questions of reverse causality whereby individuals and families who would have otherwise stayed at a healthy weight locate in neighborhoods that support their already active lifestyles and nutritional food intake.

Recently, researchers examined longitudinally the role of traffic density around the homes of children. They found that higher levels of vehicular traffic were associated with higher attained body mass index (BMI measured as kg/m^2) in children aged 10–18 [15]. Traffic is associated with several adverse exposures including increased accident danger and air pollution [16], suggesting different explanations for the positive association between traffic and attained BMI. Heightened traffic danger may discourage children from engaging in active transport by foot or bicycle for utilitarian purposes [17], and other things being equal, this would lower overall physical activity and could contribute to a positive energy balance.

Other research indicates that air pollution exposure, with traffic as a major source in many cities, may operate through inflammatory pathways to initiate metabolic processes contributing to diabetes formation [18,19]. These findings are supported by animal research showing that mice fed a fat chow diet and exposed to air pollution develop more visceral fat and insulin resistance than mice eating the same diet, but breathing purified air [20].

At this time, there are few epidemiological studies that have investigated specifically whether air pollution contributes to obesity formation in childhood, and only one study has examined traffic density effects on BMI growth [15]. A recent study suggested that early life exposure to polyaromatic hydrocarbon markers of ambient traffic-related pollution were associated with subsequent increased BMI and obesity at age seven [21]. Here we aim to assess the impact of traffic-related air pollution and traffic density near the home on the growth of BMI in a prospective cohort of children who were followed from age 5–11 in 13 Southern California communities. This paper seeks to expand on the earlier assessment of traffic as a risk factor by examining the specific pathway of air pollution exposure. In this context, the main aim of the study is to assess whether exposure to traffic and traffic-related air pollution relate to BMI growth in children.

Methods

Conceptual framework

In Figure 1, we propose the following conceptual model to illustrate the pathways through which traffic might affect obesity and cardio-metabolic disorders. Traffic could influence perceived safety and thereby affect the amount of active travel by foot or by bike. In this instance, we hypothesize that higher traffic could reduce physical activity, and as noted above, this could positively change energy balance. Previous research on this and similar cohorts has demonstrated that traffic can negatively affect active travel [22] and that this may lead to higher levels of obesity [15]. Another pathway could operate through perceived safety, noise and vibration, which all have the potential to increase stress. Stress has been associated with higher intakes of fat and carbohydrates and with cortisol and sleep dis-regulation that can affect the diet. All of these pathways, if they lead to altered eating habits, could contribute to obesity. In recent research on the same cohort, we showed that stress in the family is linked to small increases in BMI growth [23]. Finally, there is the impact of environmental and traffic-related pollution. Here the effect could operate through systemic inflammation to increase pro-obesogenic pathways mentioned above [20] or through the formation of chronic diseases that might lessen physical activity and have themselves been associated with obesity in the case of asthma [24,25]. Some components of traffic-related air pollution may contain endocrine disruptors that could be obesogens. This pathway might be enhanced through other obesogen exposures from other environmental sources such as phthalates [26]. This framework is used to guide our statistical modeling in terms of selecting variables to test for confounding and to help interpret our results where specific variables are unavailable for analyses (e.g., biomarkers of obesogen exposures).

Ethics statement

The research protocol, including informed consent forms, was reviewed and approved by the Institutional Review Board, University of Southern California. Subsequent approval was given by the Committee on the Protection of Human Subjects, University of California, Berkeley for the geographic information exposure assignment to the homes of the study subjects.

Study design

A cohort of children attending kindergarten and first grade (age 5–7 years) were enrolled during the 2002–03 school year from classrooms in 45 schools across 13 communities in Southern California (N = 4550). Parents provided informed consent and completed a detailed baseline and yearly follow-up questionnaires with information about asthma and related symptoms, demographic characteristics, physical activity, characteristics of homes, and other relevant covariates. Height and weight were measured without shoes at study entry and annually by a trained technician at the child's school.

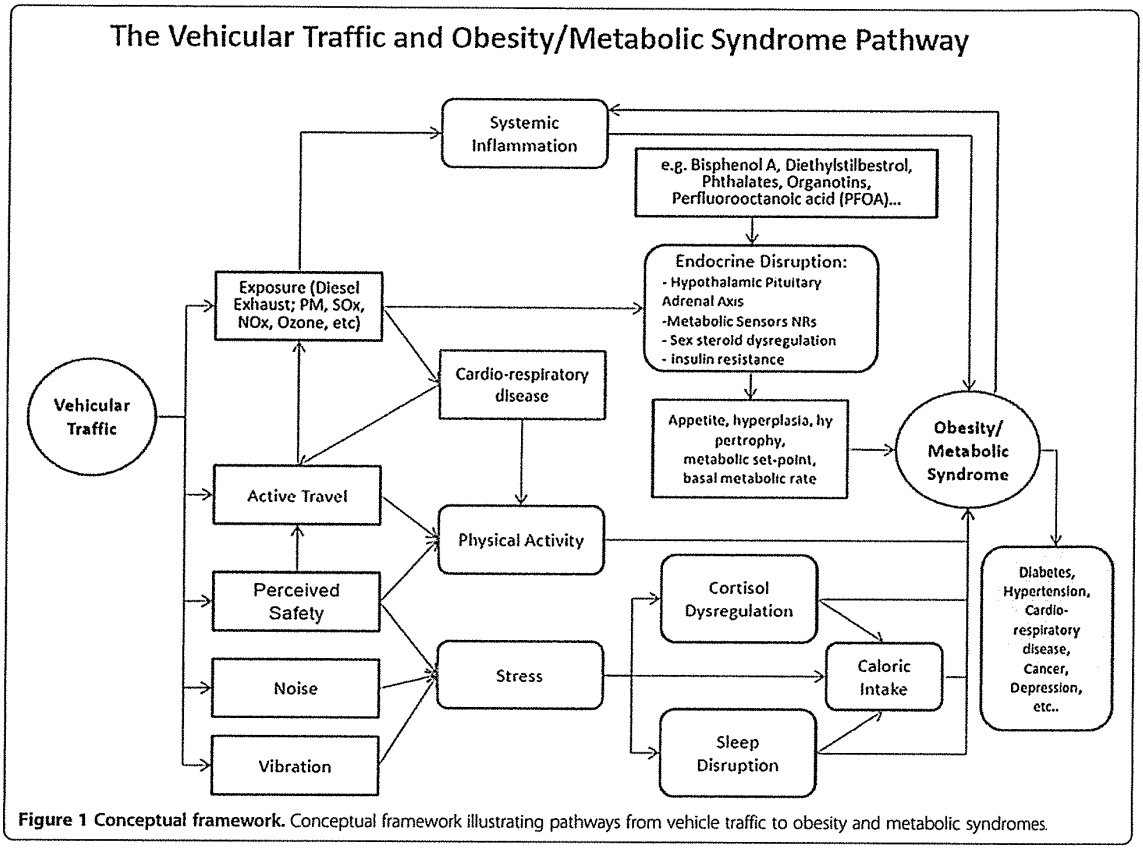

Figure 1 Conceptual framework. Conceptual framework illustrating pathways from vehicle traffic to obesity and metabolic syndromes.

Technicians followed a standardized procedure to measure height and weight using a calibrated medical scale. Measurements were recorded to the nearest 1 cm and 1 lb (0.45 kg), respectively. These objective measures of height and weight allowed for accurate calculation of BMI.

Other characteristics of this cohort have been described previously [27]. Information on demographic characteristics from questions that were asked repeatedly in yearly questionnaires was updated for this analysis. We also collected information on physical activity, mainly in the form of programmed activities and team sports (see Additional file 1 for details). The analytical data set was restricted to children who had two or more measurements of height and weight (N = 4257).

Homes of the children were geo-coded. Built-environment variables such as access to parks were calculated around the children's homes and schools and assigned to each child (see [13,15] for more detail on the built environment variable compilation). Neighborhood and community social environmental variables, such as the poverty rate available from the U.S. Census, were also assigned to the residential address for inclusion as confounders in our multilevel models.

Exposure models

Exposure to air pollution was assigned using the CALINE4 dispersion model (see Additional file 1 for details). Briefly, this model used Gaussian plume dispersion parameters with traffic data, emissions factors, and local meteorology to estimate exposure to the mixture of near-roadway pollutants at the homes of the children based on a model for the incremental increase in nitrogen oxides (NO_x) above regional background levels, as previously described [27]. Exposures for freeway and non-freeway sources were assigned to the baseline address of the children.

Traffic exposure variables were based on the California Department of Transportation Functional Class (FC) data for the year 2000. The annual average daily traffic (AADT) volumes were conflated to the TeleAtlas road network [28]. Traffic data were based on continuous measurements on freeways, highways, and some major arterials, and intermittent measurements within the previous three years on other major roads. The spatial pattern of traffic density changes slowly over time and the

temporal period used here likely supplies a good representation of the longer-term traffic patterns around the subjects' homes for our study period. As described elsewhere, a kernel density function was estimated to smooth the influence of traffic around the home [15]. This function down-weighted the influence of traffic exposures as a function of Euclidian distance away from the child's home. Based on previous evidence [15], traffic density was examined within 150 m of the home.

Statistical methods

A multilevel linear model was used that allowed for examination of the effects that risk factors have on attained BMI level at age 10 and the rate of growth during the follow-up period between the ages of 5–11 years [29,30]. This modeling approach properly adjusts for age- and sex- specific effects on BMI growth in children, provides an effective mechanism for assessing effects of risk factors on BMI level and growth, and also implicitly adjusts for baseline levels of BMI. Letting c, i and j denote the study community, child and year of measurement, respectively, the following multi-level linear model was used to examine the effect of an exposure variable (e.g., NOx) at the individual level, X_{ci}, on BMI, Y_{cij}:

$$Level\ 1: \quad Y_{cij} = A_{ci} + B_{ci}t_{cij} + e_{cij} \tag{1}$$

$$Level\ 2a: \quad A_{ci} = A_c + \beta_1 X_{ci} + \delta_1 Z_{ci1} + \cdots + \delta_q Z_{ciq} + e_{ci} \tag{2}$$

$$Level\ 2b: \quad B_{ci} = \beta_0 + \beta_2 X_{ci} + f_{ci} \tag{3}$$

where t_{cij} denotes age of participants at time of BMI measurements (centered at 10 years of age), A_c denotes town specific intercepts, and $Z_1, \ldots, Z_q$ denote adjustment factors such as sex, and race/ethnicity categories. Our results were obtained by combining equations (1–3) to fit the following unified mixed effects model:

$$Y_{cij} = A_c + \beta_0 t_{cij} + \beta_1 S_{ci} + \beta_2 S_{ci} \times t_{cij} + \delta_1 Z_{ci1} + \cdots + \delta_q Z_{ciq} + e_{ci} + f_{ci} t_{cij} + e_{cij} \tag{4}$$

In Eqn (4), β_1 and β_2 correspond to the simultaneously estimated effects of exposure on BMI level attained at age 10 (i.e., examining the main effect between individuals) and also the yearly slope of change in BMI during the follow-up period, respectively. Random effects for community were used in models that assessed confounding by community level covariates such as poverty and crime rates, essentially leading to three-level models.

This modeling approach allowed for examination of the effects of covariates of interest at various levels: between times (within individual), between individuals, and between other levels of spatial aggregation (e.g., school or community). The base model included indicator functions for community, gender, and race or ethnicity. A final model was then developed by including all additional confounders that individually changed the effect of interest on the attained BMI level at age 10 (level) or the rate of change in BMI levels (slope) by at least 10%. All confounders were included for both "level" and "slope". Analyses were conducted using SAS (Cary, NC, U.S.) and R (Vienna, Austria) statistical software packages.

In these multilevel models, more than 50 confounding variables were screened at the individual, neighborhood, school, and community scales. As a sensitivity analysis, models with both random and fixed effects clustered on the schools of the children were also run.

Results

The mean age of children at study entry was 6.6 years (standard deviation (SD) 0.65; range 4.5-8.9). Average BMI was 16.79 at study entry (SD 2.81) (Table 1). By year 5 of the study BMI had increased approximately 2.6 units to 19.35 (SD 4.21) with boys showing a slightly greater increase. Based on Centers for Disease Control percentiles between the 85th and 95th percentile, rates of overweight were 14.4%. Obesity rates measured as BMI scores equal to or greater than the 95th percentile were 15%. The growth curves for BMI in boys and girls are shown in Figure 2. The slope of the growth curve over the follow-up period did not deviate from a linear trend.

Traffic density at 150 m radius had a positive, but borderline significant ($p < 0.1$) association with the intercept and the slope of BMI growth curves of the children (Table 2). Further evaluation of the traffic effects revealed that they were confounded by other variables, particularly whether the questionnaire had been completed in Spanish, suggesting the child was from a family of recent immigrants from Latin America. A final model included asthma status of the child, the language used to complete the questionnaire (Spanish or English), whether the child was exposed to second-hand smoke in the home, the parental level of education, the gamma index (a measure of the connectivity of the street network around the child's home which affects walking distances), the number of fast food outlets within 500 m of the child's home, greenness around the home as measured by the normalized difference vegetation index, the number of active recreational programs for children offered within 5 km of the home, and traffic density at 150 m (Table 2). In this fully-adjusted model, the effect of traffic within 150 m remained positive on the slope, but was reduced by more than 20% by the confounders and was no longer borderline significant. Of note, we tested several variables measuring various aspects of physical activity or participation in sports, but none of these variables met our inclusion criteria for confounding.

Table 1 Participant baseline[a] characteristics, exposures and potentially confounding variables used in the analysis

Participant characteristics	No.	(%)	Mean	(SD)
Race/Ethnicity				
African American	122	(2.68)		
Asian	145	(3.19)		
Hispanic	2462	(54.11)		
Non-Hispanic White	1664	(32.18)		
Other	357	(7.85)		
Gender				
Male	2297	(50.51)		
Female	2251	(49.49)		
Individual and household characteristics				
Parental Education				
Less than High School	905	(21.75)		
High School	781	(18.77)		
Above High School	2575	(59.48)		
Second hand smoke				
No one ever smoked in the house	3962	(97.22)		
Anyone ever smoked in the house	309	(7.23)		
Ever Asthma				
No	3501	(86.13)		
Yes	564	(13.87)		
Spanish Speaker				
No	3417	(75.1)		
Yes	1133	(24.9)		
Local home or school environment				
Having no food stores within 500 m road network buffer				
No	1980	(48.09)		
Yes	2137	(51.91)		
Street connectivity (Gamma index 500 m buffer)	4117		0.4	0.06
Parks and recreation (unit: acre in 500 m buffer)	3968		4.95	10.6
NDVI green cover[b] (in 500 m buffer)	4117		0.09	0.10
Recreation programs within 5 km	4117		29.7	34.20
Community social context				
Proportion of unemployed males and females			0.076	0.02
Community level violent crime rate (Crimes per 100,000 population)	4550		511.73	268.04
Air pollution and traffic				
Total NO_x (parts per billion)	4464		49.24	104.93
Traffic density within 150 m of the home	4464		19.49	18.82
Primary outcome				
BMI at baseline	4550		16.79	2.81
Males	2297		16.87	2.81
Females	2251		16.70	2.80
BMI at the end of follow up	4550		19.35	4.21
Males	2297		19.50	4.36
Females	2251		19.19	4.15
BMI CDC percentile at baseline				
85 > BMIp	3201	(70.35)		
85 ≤ BMIp < 95	660	(14.41)		
95 ≤ BMIp	684	(15.03)		

[a]First observation of the subjects in the first year of the study is N = 4550 with restriction of non-missing BMI and with two or more observations; numbers of subjects in the table vary due to missing covariate values.
[b]Normalized difference vegetation index derived from Landsat satellite images.

In the screening of the air pollution variables, non-freeway NO_x levels were significantly and positively associated with BMI at age 10 and the rate of growth over the four year follow-up period, while the freeway-related exposures were not associated with BMI growth, consistent with other previous studies on respiratory health [27]. The association between BMI and non-freeway NO_x was reduced but remained significantly elevated in models containing the same variables as those in the fully adjusted traffic density model described above and with those chosen specifically to confound NO_x (Table 2). Again none of the physical activity variables met the inclusion criteria as confounders. Interaction by gender was tested, but no significant evidence of difference in the effects on boys and girls was found.

Confounders at the community and school levels were further tested by including the average terms for each level and the individual deviations from the mean of the level. Neither community level crime nor poverty confounded the within-community effect of air pollution. The impact of the school level was then tested by including a fixed effect for school in the model, but air pollution remained significantly and positively associated with BMI growth with little change in the coefficient. This suggests that the school level variables did not confound the air pollution effect on BMI growth.

Discussion

We hypothesized that traffic density and traffic-related air pollution would positively associate with longitudinal growth in BMI. In this cohort of children from 13 communities across Southern California, traffic-related air pollution exerted a significant effect on BMI growth and

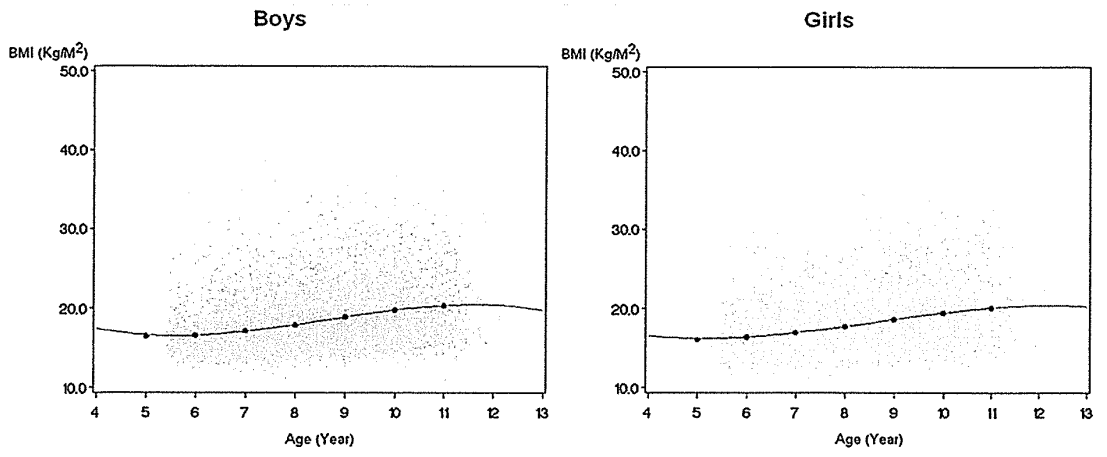

Figure 2 BMI growth curves for boys and girls over the follow-up. Points show individual BMI measures for the subjects.

BMI level attained at age 10. Evidence of effects for traffic density was found in unadjusted models. This effect was confounded in fully adjusted models, although the effects did remain elevated.

Comparing children in the highest 10% of traffic-related air pollution exposure to those in the lowest 10% of exposure yielded a 0.39 BMI unit increase in the attained BMI level at age 10. This translated into a 13.6% increase in the rate of average annual BMI growth. These effects may have large population impacts because traffic-related air pollution is a ubiquitous exposure that affects billions of people globally [31], and in many countries traffic is increasing at a higher rate than the rate of population growth [32].

Examining the effects at different times during the follow up helps to interpret the results. Figure 3 shows the BMI effects for the children in the lowest and highest deciles. The BMI range between the lowest and highest is shown as the middle line for reference. As the children get older, the effects accumulate, and the slope difference

Table 2 Effects of traffic density or traffic-related air pollution on BMI level (intercept) and growth (slope)

	Combined effect modeling	
Exposure based on 10-90th percentile contrast	Male and Female	
	Intercept β (SE)	Slope β (SE)
Traffic density[a]	0.0012* (0.0006)	0.0002* (0.0001)
Non-Freeway NO_x[a]	0.3831** (0.1552)	0.0861** (0.0255)
Traffic density[b]	0.0012* (0.0006)	0.0002 (0.0001)
Non-Freeway NO_x[b]	0.3867** (0.1552)	0.0873** (0.0255)

**p < 0.05.
*p < 0.1.
[a]Models include the same confounders: whether the child has ever had asthma, parental education as a marker for socioeconomic position, whether the questionnaire was answered in Spanish as a marker for recent immigrant status, normalized difference vegetation index within 500 m of the home as a measure of green cover, street connectivity as measured by the gamma index, recreational programming within 5 km of the home, and fast food access within 500 m of the home.
[b]Confounders selected based on modeling procedure described in the methods for each exposure. The traffic density model includes parental education as a marker for socioeconomic position, whether the questionnaire was answered in Spanish as a marker for recent immigrant status, normalized difference vegetation index within 500 m of the home as a measure of green cover, and recreational programming within 5 km of the home.
The non-freeway NO_x model includes parental education as a marker for socioeconomic position, whether the questionnaire was answered in Spanish as a marker for recent immigrant status, normalized difference vegetation index within 500 m of the home as a measure of green cover, street connectivity as measured by the gamma index, recreational programming within 5 km of the home, and fast food access within 500 m of the home.
All of the above models include indicator functions for community of residence and variables for sex and race or ethnicity.

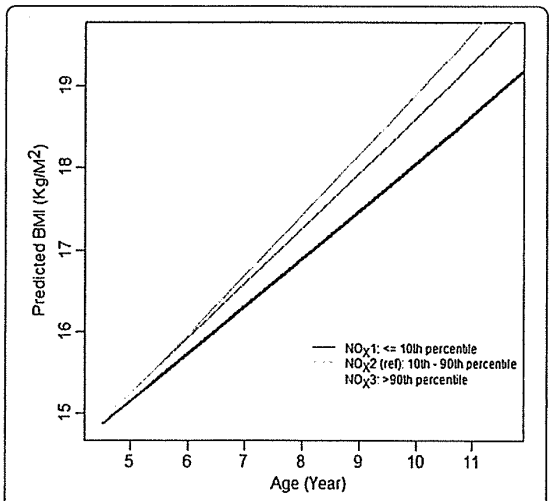

Figure 3 Predicted BMI. Plot of predicted BMI comparing children in the 10th and the 90th percentiles with the 10-90th percentile exposure contrast shown for reference.

between the lowest and highest deciles becomes more pronounced. By age 10 or 11 the difference is about 0.4 – 0.5 of a BMI unit.

Traffic density and traffic-related air pollution could not be tested in the same model because traffic density is an input variable to the dispersion models, and therefore the two variables are collinear. Traffic-related air pollution nonetheless was not confounded by other variables, suggesting that air pollution exerted a stronger effect on BMI growth than traffic density. This result was insensitive to which individual and neighborhood built environment confounding variables were used in the model. Based on the sensitivity analyses, variables at the school and community level do not confound the association between BMI and traffic-related air pollution.

The findings here differ from the only other study that examined the impacts of traffic density on BMI growth [15], which was conducted among an older cohort of children in 10 of the same study communities and used similar statistical techniques. With the same metric of traffic density within 150 m around the home, the earlier study found significant effects that were not confounded by other individual or built environment variables or community-level variables such as poverty. This difference in findings from the two cohorts may have resulted from mobility differences by age. Most of the children in the present analysis were less than 10 years old for most of the follow up, and children of this age are less likely to walk on their own than older children who were followed for the earlier research [15]. Qualitative research suggests that parents of children aged less than 10–11 perceive many barriers to allowing children to move freely in urban areas, but the same study indicates that at this age, which corresponds to the end of primary school, parents do begin to afford increased license to engage in physical activity alone or more likely in groups of peers [33]. Quantitative research using global positioning systems to track children supports the qualitative research, indicating that there is a large rise in the proportion of children allowed to range freely around the ages of 10–11 [34]. Therefore, the pathway of reduced physical activity from traffic danger in younger children may be less pronounced in older children, because fewer of the younger children exhibited independent mobility on average. The earlier study on traffic density did not test for associations with traffic-related air pollution.

Reliance on the CALINE4 dispersion model limited our ability to discern which elements of the traffic pollution mixture were most important. Although we used NOx as our indicator of traffic-related pollution, this molecular gas had strong correlations with CO, NO_2, and $PM_{2.5}$ estimates from the CALINE4 model, with correlations greater than 0.9 (see Additional file 1 for further details). We found non-freeway NOx had the association, while freeway NOx was not robust to confounders. We interpret the lack of effect from the freeway NOx as resulting from a small proportion of the total cohort who lived in proximity to freeways, rather than an attribution to a specific source from a different type of roadway. While the results indicate that traffic-related pollution likely has a stronger effect than traffic density, we are unable to identify which specific components of the traffic mixture were responsible for the effects.

Another limitation of this study related to the lack of information on food intake. Food access was controlled in the models, but dietary factors could not be directly evaluated. Given what is known about the association between lower socioeconomic position and higher traffic-related pollution exposures in California [35], some of the effects observed here may be confounded by dietary variables that are also associated with lower socioeconomic status, such as intake of sugar and fats [36]. Socioeconomic status in the home and neighborhood was controlled for, which reduces the chance of residual confounding relating to socioeconomic status, but confounding by food intake, which might be associated with air pollution through socioeconomic status, cannot be directly ruled out.

To address the concern about diet, information on dietary intake in an older cohort (ages 10–18) of nearly 2000 children in 10 of the same study communities as in the current study [37,38] was used to generate variables on macronutrients including total caloric, protein, carbohydrate, saturated fat, mono unsaturated fat, and cholesterol intake. A statistical analysis that controlled for community of residence, race, sex, and parental education as a marker of SES was performed, and for a wide array of traffic or traffic-pollution indicators there was no association between the total caloric intake and the traffic-pollution estimates or traffic density measures. A weak, borderline significant association between daily grams of carbohydrate consumption and nitrogen dioxide from non-freeway sources was observed, but the coefficient was very small. Equivalent diet information on the specific cohort used in our paper is not available, but the relationships between the traffic or pollution variables and food intake should be similar in both cohorts. Given that there was no difference in total calories or in any other macronutrient categories, the chance of confounding by unmeasured diet variables is limited.

Although we cannot rule out self selection of potentially more health-conscience families into areas with lower pollution, our mixed effects modeling framework properly controls for baseline BMI. As a result, the influence of self-selection is accounted for with subject-to-subject variability due to baseline characteristics. While self-selection could influence the trajectory, control for baseline characteristics that is inherent to our modeling framework makes it more likely that our results are from

an ongoing influence of the environment and not some other factors.

The effects of pollution are significant, and the temporal pattern is consistent with the hypothesis that the inflammatory effects of air pollution predispose children to obesity in a similar way to what has been observed in laboratory experiments [20]. By analogy, this pattern is also corroborated by human epidemiological studies finding associations between metabolic disorders and air pollution [18,19]. Another explanation is possible; in areas of high traffic, children and their parents may have a heightened sense of danger that reduces activity by restricting the mobility of families [39]. In this cohort, however, traffic effects were not significantly associated with BMI growth or attained level after controlling for confounding variables. As illustrated in our conceptual framework presented in Figure 1, there are several other pathways from stress resulting from noise or from other obesogens, which could be leading to higher BMI growth in children, but we are unable to test such pathways directly. Future research may usefully address these other pathways along with traffic pollution exposures.

Conclusions

This paper provides evidence that traffic-related air pollution is associated with the development of obesity in children. Traffic pollution may be controlled via emission restrictions; changes in land use that promote jobs-housing balance and use of public transit and hence reduced vehicle miles traveled; promotion of zero emissions vehicles; transit and car-sharing programs; or by limiting high pollution traffic, such as diesel trucks, from residential areas or places where children play outdoors, such as schools and parks. These measures may have beneficial effects in terms of reduced obesity formation in children.

Additional file

Additional file 1: Additional information on physical activity and exposure assessment.

Competing interests

Dr. McConnell has received research support from an air quality violations settlement between the South Coast Air Quality Management District, a California state regulatory agency, and BP. The authors have no other conflicts of interest to disclose.

Authors' contributions

Conceived and designed the experiments: MJ RM JW KB. Performed the experiments: RM RC CL FL. Analyzed the data: MJ RM JW RC CL GD FG. Wrote the first draft of the manuscript: MJ RM JW GD FL KB. Contributed to the writing of the manuscript: MJ RM JW RC CL GD FG FL KB. ICMJE criteria for authorship read and met: MJ RM JW RC CL GD FG FL KB. Agree with manuscript results and conclusions: MJ RM JW RC CL GD FG FL KB. All authors read and approved the final manuscript.

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A Model for Estimating NO_x Emission Reductions after Closing Drive-Thrus

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ABSTRACT

In many areas of the United States, air quality challenges are caused by on-road mobile sources. All non-attainment regions must develop strategies so that the regions' air quality can attain the National Ambient Air Quality Standards. With implementation of the new, more stringent 75 ppb ozone standard over the next several years, new innovative strategies for meeting air quality goals must be considered. The North Central Texas Council of Governments (NCTCOG) is considering one such measure. NCTCOG is contemplating a restriction on drive-thru activity. While the exact policy has not been determined, the magnitude of the potential air quality improvement must be investigated. After determining the magnitude of the improvement, other policy issues such as social and public acceptance and feasibility can be examined.

This study develops a methodology for estimating emission benefits associated with drive-thru restrictions by characterizing a drive-thru as an *M*/*M*/1 queuing system. Using data collected from a diesel truck during a field experiment, the researchers formulate emissions factors to represent the emissions associated with different vehicular activities (e.g. moving forward, idling, and moving backward) at the facility. The researchers formulate the emissions attributable to each queuing system state. After collecting arrival and service rates during morning (7-10 a.m) and lunch (11 a.m – 2 p.m.) periods at a fast food restaurant, the team estimates drive-thru emissions during each period. At this site, a drive-thru closure will result in a 61% nitrogen oxide (NO_x) reduction over the morning hours and a 67% NO_x reduction over the lunch period.

INTRODUCTION

According to EPA estimates, in 2003, on-road transportation sources emitted 36% of nitrogen oxides (NO_x), 63% of carbon monoxide (CO), and 29% of volatile organic compounds (VOCs) in the US (figures not including fires) [1]. Despite improvements in vehicle emission control systems and resulting decreases in the amount of pollutants emitted per mile traveled, the total quantity of air pollution from mobile sources has increased in recent years, due to increases in the total number of vehicles on the road and in miles traveled per vehicle. Between 1970 and 2004, total vehicle miles traveled (VMT) in the US increased by 171% [2]. In addition, as industrial sources like electric utilities come under more stringent regulation, on-road mobile sources will compose a larger percentage of the remaining emissions to be controlled.

In development of the 85 parts per billion (ppb) 8-hour ozone State Implementation Plan (SIP) for the Dallas-Fort Worth (DFW) ozone non-attainment region, closing drive-thrus during ozone season was considered. As a short-list measure, closing drive-thrus (fast food restaurants, banks, pharmacies, and dry cleaners) was evaluated for its potential emission benefit, cost effectiveness, implementation feasibility, and social/public acceptance [3]. The measure was not adopted in the final SIP because it was not SIP eligible (i.e. emissions from drive-thrus were not contained in the region's emissions inventory.)

In the analysis of potential SIP short-list measures, emission reductions associated with closing drive-thrus in DFW were estimated to be 0.01-0.05 tons/day NO_x and 0.04-0.19 tons/day VOCs, according to a method given in the Texas Guide to Accepted Mobile Source Emission Reduction (MOSER) Strategies Handbook [3,4]. The MOSER methodology estimates daily emission reductions due to restrictions on drive-thru use in g/day as follows:

$$\text{Daily Emission Reduction} = A - B + C \tag{1}$$

Amount of idling exhaust emissions generated before use-restrictions

$$A = N_v * t_B * EF_I \tag{2}$$

Amount of idling exhaust emissions after use-restrictions are in place

$$B = (1 - F_{park}) * N_v * t_A * EF_I \tag{3}$$

$$C = F_{park} * N_v * EF_{HS} \tag{4}$$

where EF_I = Idling emission factor (NO_x, VOC, or CO) (g/veh/hr)
F_{park} = Vehicle fraction that park instead of use drive-thru facility due to restriction
N_v = Average number of vehicles using the drive-thru facility per day
t_A = Time spent in queue after implementation of restriction per vehicle (hr)
t_B = Time spent in queue before implementation of restriction per vehicle (hr)
EF_{HS} = Hot-start emission factor (NO_x, VOC, or CO) (g/veh/trip)

In the SIP analysis for DFW, N_v was assumed to be 100,000, and F_{park} was assumed to be 100% and 50%. Based on information from QSR Magazine [5], t_B was taken as 10 minutes, and t_A was taken as 3 minutes (0.167 hour and 0.05 hour, respectively).. The idling and hot-start emission factors came from MOBILE.

In estimating emissions, MOSER thus accounts for drive-thru idling emissions, and hot start exhaust emissions from vehicles that park; however, the MOSER strategy does not account for emissions associated with backing out of a parking space nor driving within the parking lot of

the facility. A literature survey found no models or methodologies besides the MOSER methodology for estimating emission reductions associated with closing drive-thrus.

With implementation of the new, more stringent 75 ppb ozone standard over the next several years, a measure restricting drive-thru activity is likely to be included in the next DFW SIP, since drive-thru emission estimates are now available to include in the region's emissions inventory. Not only DFW but also other ozone non-attainment areas across Texas and around the country may want to consider restricting drive-thru use as a measure to attain the 75 ppb ozone standard.

This study aims to improve on the existing methodology for estimating emission benefits associated with drive-thru restrictions, by measuring real-world emission factors associated with idling, cruising, and backing up. Additionally, this study characterizes the drive-thru as an *M*/*M*/1 queuing system to more accurately determine customer idling time. The researchers formulate the emissions associated with each queuing system state, and estimate emissions associated with parking. Integrating a queuing system model with emissions that correspond to each the system state should improve the accuracy of emission benefit estimates for closing drive-thrus.

METHODOLOGY

On-Board Data Collection

This study uses a portable emission measurement system (PEMS) to collect field data; this study's PEMS is the Horiba On-Board Measurement System OBS-1300. The OBS-1300 consists of two on-board gas analyzers, a laptop computer equipped with data logger software, a power supply unit, a tailpipe attachment and other accessories. The OBS-1300 collects second-by-second measurements of nitrogen oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), exhaust temperature and pressure, and vehicle position. HC, CO, and CO_2 are measured using heated non-dispersive infrared (HNDIR), and NO_x is measured using a non-sampling type zirconium sensor. Only the NO_x emission results are reported in this paper. The Dallas/Fort Worth (DFW) region must focus on reducing NO_x emissions because the region is NO_x-limited for ozone, which means that reducing NO_x emissions to decrease ozone concentrations is more effective than reducing VOC emissions.

After attempting to rent a diesel vehicle through a rental car company, the researchers selected a 26' International truck model S1900 (around 1983-1985) and installed the OBS on it. The truck's 190 hp diesel engine had 6-inline cylinders with a turbo charger. The diesel truck was chosen because the OBS-1300 only measures NO_x accurately from diesel vehicles; gasoline vehicles with catalytic converters produce an ammonia byproduct that interferes with the NO_x measurements [6]. Although not many 26' trucks are likely to use drive-thrus, its use is still valid because the researchers' interests center on the percent reduction in emissions between vehicles using the drive-thru and parking. The study assumed that this percent reduction in emissions would be similar for all vehicles. The researchers can test this assumption in future studies.

To simulate vehicle movement at a fast-food restaurant, the truck was driven in an empty parking lot. First, the engine was started and emissions were measured while the truck idled for 20 minutes. Next, emissions were measured as the truck accelerated from a stop; traversed a straight-line distance of 20, 40, 60, 80, 100, 125, 150, 175, 200, 250, 300, 350, or 400 feet at an appropriate parking lot cruising speed; and decelerated to a stop. Such acceleration/cruise/deceleration movements would be representative of a vehicle performing the following activities:

- entering the parking lot from a slowed speed (although perhaps not a stop), accelerating and then traversing the parking lot at a constant speed, and decelerating and stopping at the ordering location;
- accelerating from a stop at the ordering location, traveling at a constant speed toward the pick-up window, and decelerating and stopping there;
- all movements within the queue, when the system transitions between states and each vehicle moves forward one car length;
- accelerating from a stop at the pick-up window, traveling at a constant speed toward the parking lot exit, and decelerating to a stop to wait to enter the street.

The research team assumes that turns within the parking lot would not significantly impact emissions or speed, compared with traversing a straight line. Five repetitions were made of the acceleration/cruise/deceleration combinations for each straight-line distance; since thirteen distances were traversed, the researchers collected data for sixty-five runs. Finally, the team measured emissions as the truck backed out of a parking space five times.

Drive-Thru Customer Data Collection

To supplement the emissions data collected in the parking lot, drive-thru customer data was collected at a McDonald's in Arlington, Texas near the University of Texas at Arlington. The McDonald's has an ordering location and one pick-up window (no payment window). The following data was collected on a Tuesday/Thursday during the breakfast peak (7-10 a.m.) and lunch peak (11 a.m. – 2 p.m.):

- Time that customer entered the ordering queue;
- Time that customer started to place order;
- Time that the customer took to place an order;
- Time that customer left the pick-up window;
- Time that the customer took to pick up order;
- Number of drive-thru customers arriving hourly.

RESULTS

This section presents the methodology that the research team used to estimate emissions during the breakfast and lunch peaks at a fast food restaurant with a drive-thru. The first section analyzes the data generated during the emissions experiments with the International truck model S1900. This data is used to create emission factors for idling and vehicle movements within the parking lot. The section that follows describes the drive-thru as an *M*/*M*/1 queuing process. After describing the queuing process, the next section formulates the emissions associated with each queuing system state. The last section compares the emissions reduction that occurs when the drive-thru is closed and all customers must park and enter the establishment.

Emission Factor Estimation

Figure 1 shows NO_x idling emissions in μg/sec as a function of time. Average emissions from 0-5 minutes are 451 μg/vehicle/second. Average emissions from 5-20 minutes are 560 μg/vehicle/second. The engine likely changed to a different operation mode at five minutes. Since idling times in a drive-thru line without any change in location will typically be less than five minutes, an idling emission factor of $EF_I = 451$ μg/vehicle/second will be used.

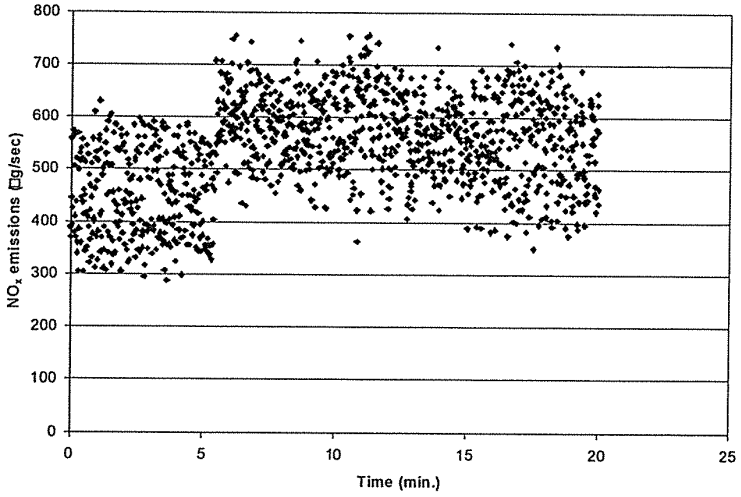

FIGURE 1 NO_x idling emissions (μg/sec) vs. time (min.).

Figure 2 show travel time as a function of parking lot distance traversed. As expected, the travel time increases as the distance traversed increases.

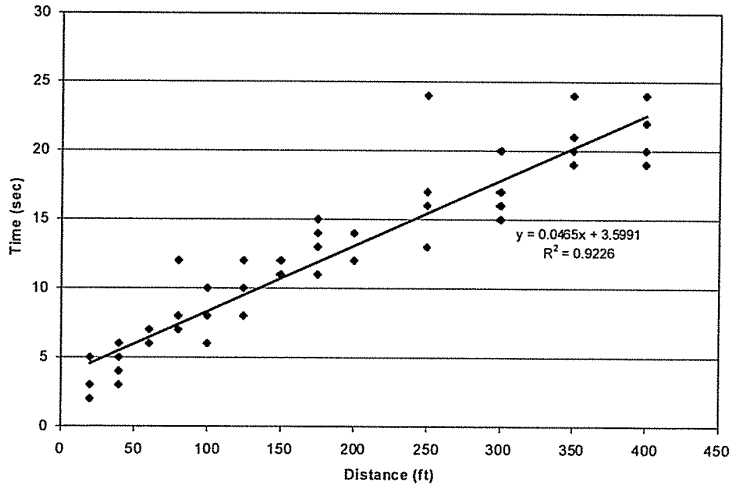

FIGURE 2 Travel time (sec) vs. distance (ft).

Figure 3 shows NO_x emissions in μg/sec for each acceleration/cruise/deceleration combination as a function of straight-line parking lot distance traversed. Since five runs are made for each straight-line distance, five data points are plotted for each distance. The average value from Figure 4 is 767 μg/sec.

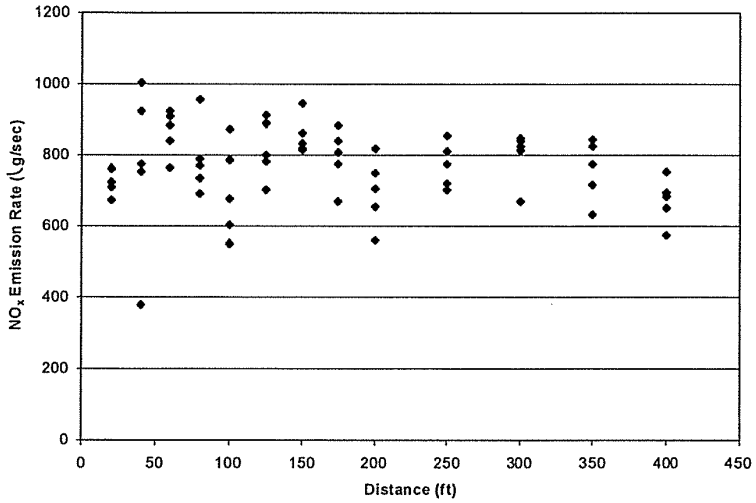

FIGURE 3 Average NO_x emission rate (μg/sec) vs. distance traversed (ft).

Figure 4 shows total NO_x emissions in μg for each acceleration/cruise/deceleration combination as a function of straight-line parking lot distance traversed. The researchers fit an equation to facilitate the formulation of emission factors associated with the distance that a vehicle travels between stops within the parking lot. Equation (5) can be used to calculate the EF_D for any distance within the parking lot.

$$EF_D = 324\left(d^{0.6527}\right) \tag{5}$$

Where d represents the distance traveled measured in feet, and EF_D is in μg/vehicle.

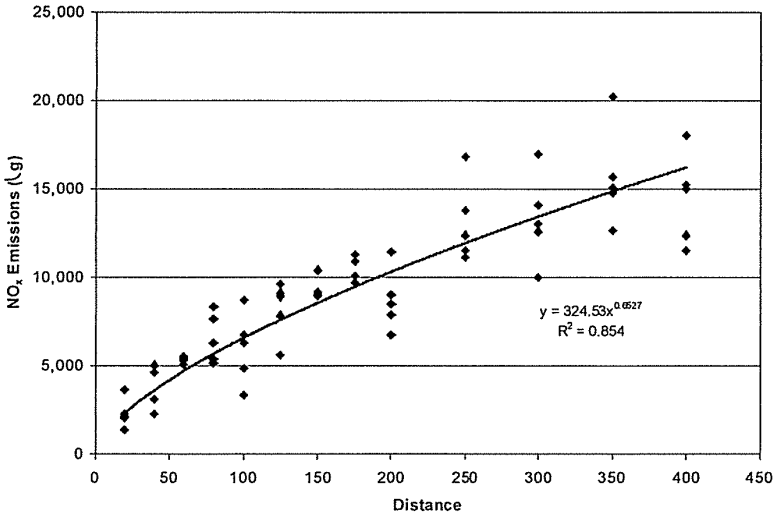

FIGURE 4 Total NO_x emissions (μg) vs. distance traversed (ft)

Figure 5 shows average NO_x emissions in μg/sec as a function of average velocity. Since there was not much variation in vehicle speed, there was not a noticeable change in emission rate with speed. As was the case with emission rate vs. distance traversed, no trend or pattern exists.

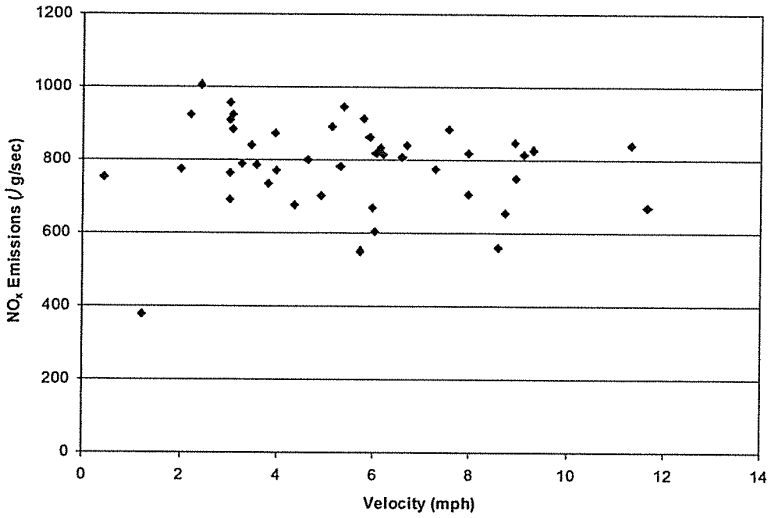

FIGURE 5 Average NO_x emission rate (μg/sec) vs. velocity (mph).

The team has collected five repetitions of the vehicle backing out of a parking space. The average emissions per reverse maneuver are 7345 µg, so a reverse maneuver emission factor of $EF_R = 7345$ μg/vehicle will be used.

Queuing System Characterization

A restaurant drive-thru may be characterized as a queuing system with a single server. The researchers propose that both the interarrival and interservice times have a negative exponential distribution. Typically, one can use a Chi-Square Test to determine if a data set fits a particular distribution. Unfortunately, this study has limited data collection; therefore, performing a Chi-Square test provides reduced utility. The changing arrival rates during the study period (see Table 1) exacerbate this problem. Additional data collection must be conducted to determine how arrival and service rates vary by time of day because the observed variability may result from the stochasticity in the rates or may represent an actual rate change. At this time, the frequency distributions of the morning and lunch arrivals and services (Figures 6 through 9) show that the interevent times generally follow a negative exponential distribution.

TABLE 1. Hourly Volumes Using Drive-Thru

Time	Vehicles
7-8 a.m.	117
8-9 a.m.	98
9-10 a.m.	80
11 a.m.–12 p.m.	71
12-1 p.m.	105
1-2 p.m.	73

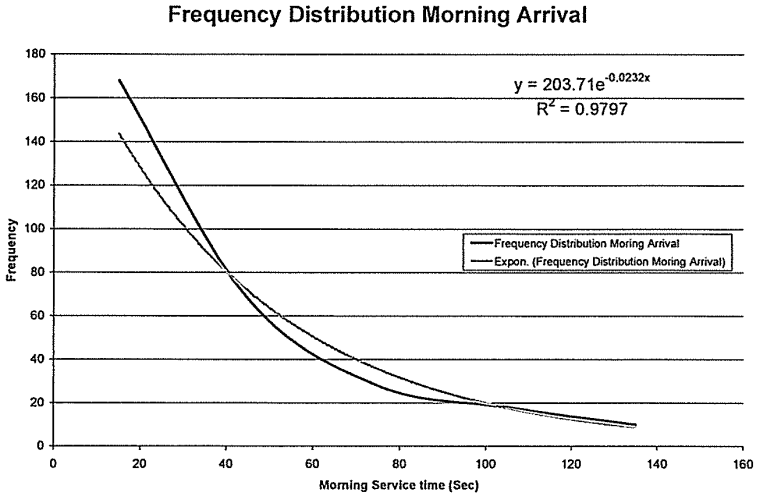

FIGURE 6 Frequency distribution of morning interarrival times

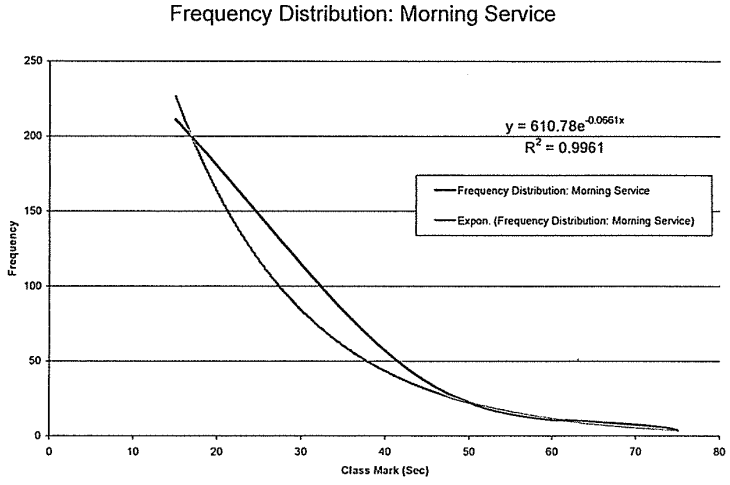

FIGURE 7 Frequency distribution of morning interservice times

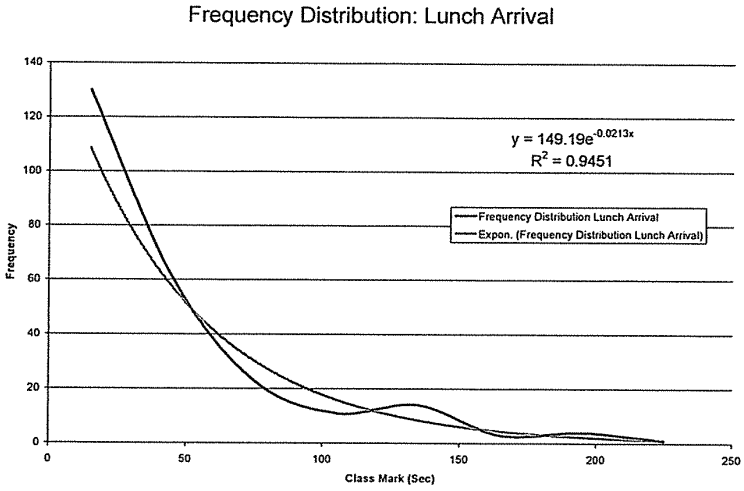

FIGURE 8 Frequency distribution of lunch interarrival times

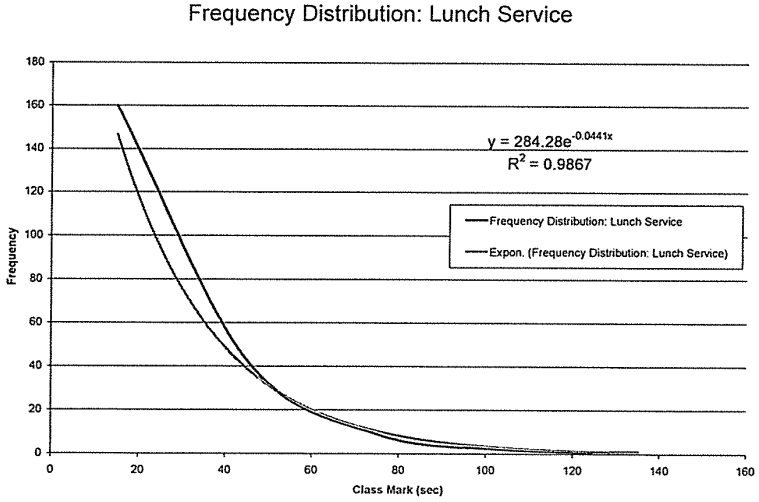

FIGURE 9 Frequency distribution of lunch interservice times

At this time, an assumption of an *M*/*M*/1 queuing system seems reasonable. In this queuing system, both the arrival and service events have a negative exponential distribution of the form:

$$f_T(t) = \begin{cases} \alpha e^{-\alpha t} & for\ t \geq 0 \\ 0 & for\ t < 0 \end{cases} \tag{6}$$

where $1/\alpha$ is the expected time between events. The assumption of a single server is based on the service at the pick up window controlling departure from the system. The service rate may not be constant for each arriving vehicle, but the simplified model is a necessary strategy as a first step in the analysis. Without a baseline queuing system, the researchers will lack a reasonable comparison when considering more complex queuing model forms. A *M*/*M*/1 queuing system is well known and the formulas associated with them may be found in any operations research textbook. This paper includes some basic terminology and formulas that are used to generate the queuing system state probabilities required for calculating the emissions associated with each system state (see the next section).

A queuing system may be represented by system states where the value of the state is determined by the number of customers in the system. When a new customer arrives, the system transitions to a higher state, and when a customer leaves, the system transitions to a lower state. The mean occurrence rate for an event depends only on the current system state. When assuming steady state conditions, these mean rates remain constant for the system. Table 1 shows that this is not likely the case; however, this assumption greatly simplifies analysis, and for many periods during the day, steady state conditions likely exist. The mean arrival rate is represented by λ, while μ represents the mean service rate. The system utilization factor, ρ, is defined in equation (7).

$$\rho = \frac{\lambda}{\mu} \tag{7}$$

The system idle time, P_0, which is the probability of the system being idle, is defined by equation (8).

$$P_0 = 1 - \rho \tag{8}$$

Equation (9) defines the probability of any system state occurring.

$$P_n = (1 - \rho)\rho^n \tag{9}$$

The researchers calculated separate λ and μ values for the morning and lunch periods. These values, as well as the emission factors and travel times within the parking lot, are summarized in Table 2. These values are integrated together in the next section to determine the emissions attributable to each system state.

Table 2. Queuing System Characteristics and Emission Factors

	Morning	Lunch		
Total Study time [Min]	180	180	Idle EF (EF_I) [μg/veh/sec]	451
Total Study time [Sec] (T)	10800	10800		
Total Drive-Thru Vehicles during Study period (V_{DT})	294	255	Reverse (EF_R) [μg/veh/reverse]	7345
Average Interarrival Time [Sec]	37.5	42.9	Avg. Time to Travel 100' [Sec] (t_{100})	9.4
Average Interservice Time [Sec]	28.6	33.3	Avg. Time to Travel 80' [Sec] (t_{80})	9.4
λ [Veh/Min]	1.63	1.42	Avg. Time to Travel 60' [Sec] (t_{60})	7.2
μ [Veh/Min]	2.11	1.84	Avg. Time to Travel 40' [Sec] (t_{40})	5.6
ρ (λ/μ)	0.773	0.772	Avg. Time to Travel 20' [Sec] (t_{20})	4.2

Rolling Emissions: $y = 324 * x^{0.6527}$ ($R^2 = 0.854$)					
Distance in Ft	EF_D in μg/vehicle		Distance in Ft	EF_D in μg/vehicle	
200	EF_{200}	10,209	100	EF_{100}	6546
180	EF_{180}	9606	80	EF_{80}	5658
160	EF_{160}	8896	60	EF_{60}	4690
140	EF_{140}	8153	40	EF_{40}	3599
120	EF_{120}	7373	20	EF_{20}	2289

Estimating Emissions

Emissions for Customers Using Drive-Thru

The researchers attribute the events that cause emissions to system states within the queuing model. During the transition to a new state, emissions occur as vehicles change locations within the drive-thru. In addition to emissions associated with the transition, the vehicles in the system remain idling except for these transitions. The idling emissions can be combined the transition emissions to calculate the total emissions.

In order to properly quantify the emissions, the site dimensions must be defined.

- L_{IN} – length of driveway from the entrance to the order window, 200 feet
- L_{DT} – length of drive-thru from the order window to the pick-up window, 100 feet
- L_{OUT} – length of driveway from the pick-up window to the exit, 100 feet
- L_V – vehicle length, 20 feet
- T – study period, 10800 seconds (3 hours)
- V_{DT} – vehicle volume (Tables 1 and 2)

Idle Emissions

The idling emissions rely on the probabilities of each system state to determine the total amount of time that the system is in each state, where the state actually corresponds to the number of idling vehicles. The transition times are removed from the total idle time. Equation (10) quantifies the idling emissions, IE_n, for each state.

$$IE_n = \begin{cases} \left(\left(P_n * T\right) - \left(\left(P_{n-1} * V_{DT} * t_{[L_{DT}-(n-1)L_V]}\right) + \left(P_{n+1} * V_{DT} * t_{L_V}\right)\right) * EF_I\right) & for \frac{L_{DT}}{n} > L_V \\ \left(\left(P_n * T\right) - \left(\left(P_{n-1} + P_{n+1}\right) * \left(V_{DT} * t_{L_V}\right)\right) * EF_I\right) & for \frac{L_{DT}}{n} < L_V \end{cases} \quad (10)$$

where $n = 1$ to ∞

Transition Emissions: Vehicle Arriving

The proposed model assumes that the ordering window is always vacant when a new vehicle arrives; therefore, the emissions in this term relate to a vehicle entering the facility and driving to the end of the queue. An arriving vehicle may stop and place an order before reaching the end of the queue. The arriving transition emissions, ATE_n, are given in equation (11).

$$ATE_n = \begin{cases} \left(P_{n-1} * V_{DT} * \left(EF_{L_{IN}} + EF_{[L_{DT}-(n-1)L_V]}\right)\right) & for \frac{L_{DT}}{n} > L_V \\ \left(P_{n-1} * V_{DT} * \left(EF_{[L_{IN}-L_V(n-(1+ROUNDUP(L_{DT}/L_V)))]}\right)\right) & for \frac{L_{DT}}{n} \le L_V < \frac{L_{DT}+L_{IN}}{n} \\ \left(P_{n-1} * V_{DT} * \left(EF_{L_V}\right)\right) & for \frac{L_{DT}+L_{IN}}{n} \le L_V \end{cases} \quad (11)$$

where $n = 1$ to ∞ and all of the emissions factors are for rolling distance, EF_D.

Transition Emissions: Vehicle Departing

The researchers assume that there are no gaps in the queue when a vehicle departs. The emissions associated with a vehicle departing include the vehicle leaving the property and all remaining vehicles pulling forward one car length. In order for a vehicle to leave the system, a vehicle has to be in the system; therefore, the system's losses are proportionally distributed amongst all non-idle states. Equation (12) presents the formulation for the departing transition emissions, DTE_n.

$$DTE_n = \frac{P_{n+1}}{\rho} * V_{DT} * \left(EF_{L_{OUT}} + n * EF_{L_V}\right) \quad (12)$$

where $n = 0$ to ∞ and all of the emissions factors are for rolling distance, EF_D.

The total drive-thru emissions can be calculated using equation (13).

$$E_{DT} = \sum_{n=1}^{\infty} IE_n + ATE_n + DTE_n \quad (13)$$

Table 3 presents the system state probabilities (equation (9)) and the emissions from each state using equation (13). The total morning emissions for the drive-thru are 16.0 grams, and the total lunch emissions are 16.1 grams.

TABLE 3. System State Probabilities and Emissions

System State	Prob.	Morning	Lunch	Emission in g	Morning	Lunch
0	P_0	0.227	0.228	E_0	0.45	0.37
1	P_1	0.182	0.172	E_1	1.00	0.92
2	P_2	0.139	0.134	E_2	1.23	1.22
3	P_3	0.105	0.104	E_3	1.42	1.44
4	P_4	0.080	0.081	E_4	1.48	1.53
5	P_5	0.061	0.064	E_5	1.45	1.53
6	P_6	0.046	0.050	E_6	1.30	1.41
7	P_7	0.035	0.039	E_7	1.14	1.27
8	P_8	0.027	0.030	E_8	0.99	1.13
9	P_9	0.020	0.024	E_9	0.84	0.98
10	P_{10}	0.015	0.018	E_{10}	0.70	0.85
11	P_{11}	0.012	0.014	E_{11}	0.59	0.73
12	P_{12}	0.009	0.011	E_{12}	0.49	0.62
13	P_{13}	0.007	0.009	E_{13}	0.40	0.52
14	P_{14}	0.005	0.007	E_{14}	0.50	0.50
15	P_{15+}	0.029	0.016	E_{15+}	2.08	1.12
SUM		**1.000**	**1.000**		**16.0**	**16.1**

Emissions for Parking Customers

The parking customers' emissions depend on the parking location, which determines the distance traveled by the parking vehicle. This study has not completed a detailed analysis of parking space utilization; therefore, the researchers have made some assumptions regarding the lot's utilization. Given that the facility has thirty-two parking spots, the study assumes that all of the parking locations are utilized with a uniform probability. The study assumes that the parking vehicles enter and leave through the same driveway, and none of the parking spaces are pull through (i.e. one reverse maneuver occurs). Furthermore, the researchers assume that a parking space is always available for a customer; there is no blocking or balking. Without an analysis of the interior operations, the researchers cannot determine the hot soak time for each parking vehicle. Future research will measure hot start emissions as a function of hot soak time and determine this time based on the interior queuing system and dining behavior.

The equation for NO_x emissions from parking customers is given by equation (14).

$$E_P = \sum_{i=1}^{m} P_i * V_P * \left(2EF_{L_i} + EF_R\right) \tag{14}$$

Where E_P = Total customer parking emissions
P_i = Probability of customer selecting parking spot i
V_P = Volume parking at facility during study period (vehicles)
EF_R = Reverse emission factor (μg/veh) = 7345 μg /vehicle
EF_{L_i} = Rolling emission factor to distance L_i (μg/vehicle)

Table 4 specifies the number of parking spaces at each distance; recall that each space has an equal probability of selection. One should note that the probability associated with selecting

different spaces may or may not differ by time of day and demand. The table also shows the emission factors associated with rolling distance from the entrance to the space, and the total emissions for the morning and lunch periods. When all of the drive-thru customers switch to parking, the morning emissions are 6.2 grams and the lunch emissions are 5.4 grams.

TABLE 4. Emissions for Parking Customers

Distance (Feet)	Parking spaces	EF_D (μgm/vehicle)		Emissions (grams)	
				Morning	Lunch
75	6	E_{75}	5425	1.00	0.87
100	10	E_{100}	6546	1.88	1.63
125	16	E_{125}	7572	3.31	2.87
Total				**6.2**	**5.4**

Reduction in Emissions due to Drive-Thru Closure

Based on existing drive-thru emissions, the percent reduction in emissions due to closing a drive-thru can be calculated as follows:

$$\text{Percent Reduction} = (E_{DT} - E_P)/E_{DT} * 100 \quad (15)$$

This calculation assumes that $V_{DT} = V_P$, or that every customer that previously used the drive-thru will now park (i.e. there is no reduction in customers). This is a conservative assumption (minimizes potential reductions due to closing the drive-thru), because in actuality, some customers may simply choose not to stop at the facility if the drive-thru is closed. However, this assumption also minimizes the negative impacts to the business. Closing the drive-thru will result in a 61% NO_x reduction over the three morning hours, and it will result in a 67% NO_x reduction over the three-hour lunch period.

CONCLUSIONS

This research represents an important step in verifying the potential emission reductions due to drive-thru closures. The reductions in NO_x emissions are in the range of 60-70% for the morning and lunch study periods. Given thousands of drive-thru locations scattered throughout the region, these reductions are likely significant and may be included in the region's SIP. This research establishes drive-thru closure as an effective strategy for reducing NO_x emissions; however, there remain numerous opportunities for further investigation into this topic.

Future efforts must address the planning agencies' next concern, which will likely focus on the policy's viability, especially in terms of the business and public response. Surveys can help address these concerns; however, a pilot study combined with surveys may be more effective. Part of this study must focus on any financial impacts on the businesses.

To broaden this research's impact, future studies should examine the potential regional impacts associated with a drive-thru closure program. One of the first keys to this effort is developing new emission factors that better represent the region's vehicle fleet as opposed to a single diesel truck; these fleet emission factors may be derived from MOBILE or through additional field experiments. If the observed benefits remain similar, this policy has the potential for extensive success. Part of extending the research to the entire region includes identifying the

different types of drive-thrus throughout the region. Each drive thru type may have very different characteristics and behaviors. Perhaps of most interest will be if any have different queuing system structures; however, another important issue relates to daily demand patterns for different facility types. Not only may the demand patterns vary, but service rates may also be affected. In addition to facility type, facility layout may influence modeling strategies.

The researchers made many assumptions in the course of this research; future research and additional data collection can begin to examine these. Understanding changes in arrival and service rates throughout the day at different facility types is a critical issue. With additional data collection, the interarrival and interservice time for each rate may be examined individually to verify that they have a negative exponential distribution. The values estimated through the modeling effort may be verified in the field. There should also be a verification of travel times and behaviors within the queue.

Finally, when considering business impacts, the queuing systems for the facilities' interiors must be investigated to determine if degradation in customer service occurs. The interior queuing systems are even more likely than drive-thrus to vary by facility type. Characterizing and quantifying these impacts remains a critical barrier to implementation that requires attention.

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RESEARCH ARTICLE Open Access

Adoption and diffusion of zoning bylaws banning fast food drive-through services across Canadian municipalities

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Abstract

Background: Healthy public policy is an important tool for creating environments that support human health and wellbeing. At the local level, municipal policies, such as zoning bylaws, provide an opportunity for governments to regulate building location and the type of services offered. Across North America, there has been a recent proliferation of municipal bylaws banning fast food drive-through services. Research on the utilization of this policy strategy, including bylaw adopters and adopter characteristics, is limited within the Canadian context. The aim of this study was to identify and characterize Canadian municipalities based on level of policy innovation and nature of their adopted bylaw banning fast food drive-through services.

Methods: A multiple case history methodology was utilized to identify and analyse eligible municipal bylaws, and included development of a chronological timeline and map of adopter municipalities within Canada. Grey literature and policy databases were searched for potential adopters of municipal fast food drive-through service bylaws. Adopters were confirmed through evidence of current municipal bylaws. Geographic diffusion and diffusion of innovations theories provided a contextual framework for analysis of bylaw documents. Analysis included assignment of adopter-types, extent and purpose of bans, and policy learning activities of each adopter municipality.

Results: From 2002 to 2016, 27 municipalities were identified as adopters: six innovators and twenty-one early adopters. Mapping revealed parallel geographic diffusion patterns in western and eastern Canada. Twenty-two municipalities adopted a partial ban and five adopted a full ban. Rationales for the drive-through bans included health promotion, environmental concerns from idling, community character and aesthetics, traffic concerns, and walkability. Policy learning, including research and consultation with other municipalities, was performed by nine early adopters.

Conclusion: This study detailed the adoption of fast food drive-through bylaws across Canada. Understanding the adopter-type characteristics of municipalities and the nature of their bylaws can assist other jurisdictions in similar policy efforts. While the implications for research and practice are evolving and dynamic, fast food drive-through service bans may play a role in promoting healthier food environments. Further research is required to determine the viability of this strategy for health promotion and chronic disease prevention.

Keywords: Policy diffusion, Policy adoption, Health promotion, Fast food, Drive-through services, Drive-thru, Zoning, Diffusion of innovations, Municipal bylaw

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Background

Healthy public policy is an important tool for creating environments that support human health and wellbeing [1, 2]. At the local level, municipal policies, such as zoning bylaws, provide an opportunity for governments to regulate how lands and buildings are used, where buildings and services are located, and for what purposes they serve [3, 4]. For example, municipal zoning bylaws can regulate construction, location, and number of fast food restaurants within a given area [2]. Consequently, municipal zoning bylaws also allow for stipulations regarding fast food restaurants types and services, including drive-through facilities, highlighting the potential of such municipal policies to foster healthier food environments [3–6]. This has implications for public health as fast food restaurants have been highly scrutinized for serving high fat and energy-dense foods, which are low in nutritional value and have been linked to overconsumption and weight gain [1, 2]. In addition, fast food drive-through services provide a convenient and easily accessible way for individuals to purchase and consume foods without exiting their vehicle, also contributing to physical inactivity and distracted driving [5, 7].

In recent years, municipalities across North America have implemented zoning bans on fast food restaurants and drive-through facilities. While a number of jurisdictions have done so with the goal of fostering healthier food environments, in many cases, the rationale for policy adoption extends beyond health. The most commonly proposed reasons for such policies included: promoting health [4, 5, 8–16]; maintaining visual appeal of the community [4, 5, 10–12, 17–19]; addressing noise, safety and traffic concerns [17–22]; protecting local economy [4, 5, 23]; environmental considerations [5, 18]; addressing noise concerns; and enhancing community walkability [5]. As an example, in 1981, the Town of Concord, Massachusetts, in the United States banned fast food restaurants and drive-in services as a means to reduce traffic congestion, as well as to preserve and enhance the natural quality of the community [3]. Similarly, in 2008, the City Council in South Los Angeles, California, unanimously passed a regulation prohibiting the establishment of new stand-alone fast food restaurants and drive-through services as a means to encourage healthier food options [4, 13].

This study is timely because of the recent proliferation of fast food drive through bans, particularly in North America. In the last several years, fast food related bylaws, restrictions, and/or policies have emerged as a topic of interest in Canada, specifically pertaining to the adoption of municipal bylaws banning fast food drive-through services. However, little is known regarding the extent and spread of these bylaws among Canadian municipalities. Further, to date, no systematic reviews have examined the impact of food-related zoning laws and health outcomes in Canadian jurisdictions [24]. Moving forward, it will be important for public health researchers and policy makers to study and evaluate fast food drive-through service bylaws across different contexts and jurisdictions. Specifically, the application of policy diffusion theory, such as Rogers' diffusion of innovations theory [25], allows for cross-jurisdictional learning of the various processes of testing and adopting innovation strategies across municipalities in Canada.

There is a critical knowledge gap in the Canadian context about the processes underlying development and adoption of fast food service related zoning bylaws to address health outcomes. As a means to address this gap and to foster cross-jurisdictional learning, the aim of this study was to identify municipalities across Canada that have adopted a bylaw that bans fast food drive-through services, as well as to characterize these adopter municipalities by the level of policy innovation and the nature of their adopted bylaw.

Methods

Study design

We adopted a multiple case study methodology to identify and characterize: (i) adopter municipalities across Canada, and (ii) the nature of the adopted fast food drive-through service bylaws. Case studies are a method used to investigate real world phenomenon by asking 'how' and 'why' [26]. A multiple case study design "refers to case study research in which several instrumental bounded cases are selected to develop a more in-depth understanding of the phenomena than a single case can provide" (p.582) [26]. A multiple case study methodology was therefore an appropriate study design to engender an in-depth understanding of the phenomenon of fast food drive-through service bans within a real-life context of multiple municipalities.

In this study, a 'case', referred to hereafter as 'adopter', was defined as a Canadian municipality that had adopted a ban on fast food drive-through services within a municipal zoning bylaw. The bylaw had to be enacted and publicly available at the time of this study (up to February 2016). Adoption was determined based on evidence of a formal bylaw, policy, official community plan, council resolution, or amendment document outlining a partial or full ban on new construction or building restrictions specific to fast food drive-through services in the municipality.

Theoretical approach

Diffusion of innovations theory [25] provided an organizing conceptual framework for bylaw analysis and characterization of adopters. This theory proposes: key characteristics of adopters (i.e., their level

of innovativeness based on five types and as reflected by their position in a diffusion curve); attributes of the innovation; and key contextual factors, such as communication channels and social networks, which are strong determinants of successful adoption. It outlines five types of innovation adopters: innovators, early adopters, early majority, late majority, and laggards [25]. In a general sense, innovators are the first to try a new idea and adopt an innovation (e.g., a fast food drive-through ban); as such, they are known to be venturesome. Early adopters are described as respectable, in that later adopters often seek the opinion of the early adopter before adopting an innovation. Next are the early majority, who are viewed as deliberate. This group interacts with peers to learn about an innovation, but rarely lead adoption of an innovation. Late majority are skeptical of new ideas and often wait for their peers to pressure them into adoption. Finally, the traditional nature of laggards results in this group being the last to adopt an innovation, and some in this group may only adopt the innovation once required to do so.

According to the theory [25], when adopters are plotted by adoption date on a graph of time against percentage of adopters, the resultant curve forms an S-shape. The position of an adopter on the curve defines their adopter-type based on the normal adoption distribution: innovator (2.5% of all adopters); early adopters (13.5%); early majority (34%); late majority (34%); and laggards (16%). In some cases, it may not be possible to plot policy adoption date on an S-shaped curve due to a small sample size [27]. Instead, researchers may consider both the date of adoption and characteristics of adopter innovativeness (as evidenced by government reports and examples of similar innovative initiatives) when assigning one of the five adopter-types.

Data collection

Identification of municipalities

Two reviewers carried out a systematic search for municipal bylaws, restrictions, and/or policies on fast food drive-through services across Canada. The search involved looking for relevant grey literature using the Google search engine, Restaurants Canada website, various Canadian municipal government websites, University of Alberta Library Canadian Newsstand Complete, and Quick Law (for municipal board orders and decisions) to identify possible municipal bylaws within each province and territory across Canada. An array of documents, such as municipal council meeting minutes and newspaper articles, were also identified by hand searching reference lists of identified sources. Where the aforementioned documents identified other municipal jurisdictions as referents, snowball sampling was employed to identify relevant documents from those newly identified municipalities. The initial search yielded documents from a total of 130 municipalities across 11 provinces and territories. The search was conducted in June 2015, and performed again in February 2016 for updates.

Identification of adopters

Adopters were identified by reviewing the source documents (i.e., copies of policies and bylaws, municipal council meeting minutes, and official community plans) to determine if: i) a fast food drive-through service ban had been considered and discussed by municipal council; and, if yes, ii) a bylaw, restriction, and/or policy or amendment was adopted. A municipality was characterized as an 'adopter' and included in the study if it met both criteria.

To identify adopters, coders followed four key steps. First, coders examined a municipality's zoning bylaw to identify: the definition of a drive-through; general provisions of the zoning bylaw; and if these zoning bylaws were adopted and/or amended. Second, in cases where there was no indication of a ban within the zoning bylaw, coders then identified drive-through related policies within a municipality's official community plan. If a ban could not be identified in the first two steps, step three was employed. Step three required coders to refer to news articles that initially identified a municipality as a potential adopter. News articles provided a source of key dates surrounding council discussion on the topic. This, in turn, informed a search within public council meeting minutes. Minutes were read to follow the decision-making process until a ban was adopted or rejected, allowing for confirmation. Finally, in cases where coders were still uncertain of adoption, municipal zoning bylaw officers and planners were contacted for clarification.

Data analysis

Characterization of adopters

As described above, diffusion of innovations theory [25] categorizes adopters into one of five adopter-types based on the relative time at which they adopt a new idea in a network or community of adopters. According to the theory, when adopters are plotted by adoption date on a graph of time against percentage of adopters, the resultant curve forms an S-shape. The position of an adopter on the curve defines their adopter-type based on the normal adoption distribution: innovator (2.5% of all adopters); early adopters (13.5%); early majority (34%); late majority (34%); and laggards (16%).

Due to the limited number of municipalities identified as adopters in this study (likely due to the relative recent emergence of this policy option), an adoption curve could not be empirically fitted on an S-shaped curve. Therefore, each identified adopter municipality was

plotted chronologically on a timeline and on a scatter plot using IBM SPSS Statistics 23 to examine policy spread. The timeline and scatter plot was then examined for trends and natural clustering of dates. Clusters of dates were grouped into adopter-types, with the innovator group having the earliest dates of adoption, followed by early adopters, early majority, and so on.

To confirm the adopter-type assignment of each municipality, two coders independently categorized each municipality using the diffusion of innovations theory definitions and key characteristics for each of the five adopter-types. Data used for this confirmation included municipal council reports outlining initial dates of policy discussion and development, newspaper articles highlighting public concerns with drive-through services, and personal communication with municipal planners and city clerks to clarify information and dates in public documents. Following the independent adopter-type assignment, the two coders and a third researcher discussed the findings. There was 100% agreement on adopter-type assignments.

Characterization of nature of bylaw

To analyze the nature of the adopter's bylaw, four characteristics were considered: geographic location of adopters; extent of ban (full or partial); bylaw intention or justification; and adopter policy learning activities (e.g., public consultation and research).

First, the geographic location of each adopter municipality was plotted on a map of Canada to identify possible geographical patterns. Adopters were plotted by province/territory and by region. For the purposes of this analysis, three regions were considered: eastern Canada region (comprising the following provinces: Newfoundland & Labrador, Prince Edward Island, Nova Scotia, New Brunswick, Québec, and Ontario); western Canada (Manitoba, Saskatchewan, Alberta, and British Columbia); or northern Canada (Nunavut, Northwest Territories, and Yukon).

Second, each adopter's bylaw was reviewed to categorize the extent of the bylaw as either a 'full' or 'partial' ban of fast food drive-through services across municipal zones. A bylaw was considered a 'full' ban if the zoning bylaw banned the future construction of fast food drive-through services across all municipal zones. In some cases, this involved 'grandfathering' in existing facilities, rather than requiring the closure of operating drive-through services. A 'partial' ban described zoning bylaws that banned fast food drive-through services in one or more (but less than all) zones within the municipality. For example, the bylaw may ban drive-through services in residential and downtown zones, but allow them in highway commercial zones.

Third, the intent of each adopter's bylaw was identified and assessed for alignment with bylaw intentions identified in the literature. Bylaw intentions identified in the literature included, in order of prevalence, related to: obesity and chronic disease [4, 5, 8–16]; protection of community aesthetics and character [4, 5, 10–12, 17–19]; traffic concerns [17–22]; safety [5, 10, 19, 20, 22]; reducing physical inactivity and sedentary behaviour [5, 8, 14, 28]; protecting local economy [4, 5, 23]; improving community nutrition [5, 9, 13]; air pollution, idling, and environmental concerns [5, 18]; decreasing inequalities by decreasing the density of fast food drive-through in low-income neighbourhoods [5, 29]; noise concerns from intercoms [19, 30]; and, improving community walkability [5].

Last, we identified policy learning activities where possible. These were grouped according to the typical policy learning activities of either public consultation or research activities. To be considered in the study, policy learning activities must have been conducted prior to policy adoption. Actions taken after policy adoption, though important, would not have influenced policy adoption and thus were beyond the scope of this study. Policy learning through public consultation included evidence of municipalities hosting public hearings to assess general interest and opposition to a potential drive-through zoning bylaw. Evidence of these hearings was found within municipal council meeting minutes and reports. Research activities included the municipality undertaking: i) a local inventory scan of fast food drive-through services and reviewing current zoning definitions and regulations; and/or ii) external research to understand zoning definitions and regulations of other municipalities across Canada.

Results

Adopters

Between January 2002 and February 2016, a total of 27 municipalities from six provinces were identified as adopters of fast food drive-through service bans through the adoption of a bylaw, bylaw amendment, or an official community plan (Table 1; Fig. 1). The identified set of adopter municipalities represents 0.7% of all Canadian municipalities ($N = 3669$) [31] and 24% of the Canadian population ($N = 33{,}476{,}688$) [32]. Of the 27 adopter municipalities, six (22.2%) were identified as innovators and 21 (77.8%) as early adopters (Table 1).

Nature of bylaws

Geographic location of adopters

After plotting adopters on a map of Canada, we discovered two parallel geographic patterns of diffusion, one in eastern Canada and one in western Canada (Fig. 2). Of the total 27 adopter municipalities, 18 (66.7%) were located in the eastern region of Canada and nine (33.3%)

Table 1 Summary of Canadian municipal zoning bylaws banning fast food drive-through services

Region[a]	Municipality	Bylaw	Date of Adoption	Partial or Full Ban	Adopter-Type
Eastern	Toronto, ON	Zoning Bylaw No. 569–2013	26-Aug- 2002	Partial	Innovator
Eastern	Markham, ON	Zoning Bylaw Amendment Bylaw 2003–151	27-May- 2003	Partial	Innovator
Eastern	Ajax, ON	Bylaw Amendment No. 65–2004, to amend Zoning Bylaw No. 95–2003	10-May- 2004	Partial	Innovator
Eastern	Windsor, ON	Bylaw Amendment 375–2004, to amend Zoning Bylaw No. 8600	21-Dec- 2004	Partial	Innovator
Eastern	London, ON	Zoning Bylaw Z.-1–081795	22-Jul- 2008	Partial	Early Adopter
Eastern	Kingston, ON	Bylaw Amendment No. 2015–82, OPA Number 29; amending Restricted Area (Zoning) Bylaw No. 8499	2-Sep-2008	Partial	Early Adopter
Eastern	Barrie, ON	Zoning Bylaw-2009-141	10-Aug-2009	Partial	Early Adopter
Eastern	Grimsby, ON	Zoning Bylaw No. 14–4	3-May-2010	Partial	Early Adopter
Eastern	Niagara Falls, ON	By-law No. 2011–137	14-Nov-2011	Partial	Early Adopter
Eastern	Hamilton, ON	Zoning Bylaw Amendment 11–276	16-Nov-2011	Partial	Early Adopter
Eastern	Halifax, NS	Downtown Halifax Land-Use Bylaw	13-Dec-2011	Partial	Early Adopter
Eastern	Innisfil, ON	Zoning Bylaw Amendment - Bylaw 050–12	18-Apr-2012	Partial	Early Adopter
Eastern	Caledon, ON	Bylaw Amendment No. BL-2012-094, to amend Comprehensive Zoning Bylaw 87,250	14-Aug-2012	Partial	Early Adopter
Eastern	Fredericton, NB	Zoning Bylaw No. Z-5	24-June-2013	Partial	Early Adopter
Eastern	Saint-Laurent, QC	Le Reglement RCA08–08–0001-17	18-Jun-2014	Partial	Early Adopter
Eastern	The Blue Mountains, ON	Official Community Plan, 2014	3-Sep-2014	Partial	Early Adopter
Eastern	Rosemont-La-Petite-Patrie, QC	Amendment of the Planning Regulations Rosemont-Petite-Patrie (01–279); Rosemont-la-Petite-Patrie (01–279-39)	3-Nov-2014	Full	Early Adopter
Eastern	Mississauga, ON	Zoning Bylaw Amendment 0018–2015	11-Feb-2015	Partial	Early Adopter
Western	Kelowna, BC	Zoning Bylaw No. 8964 - Text Amendment No. TA02–0006	18-Mar-2003	Partial	Innovator
Western	Vancouver, BC	Zoning & Development Bylaw No. 3575, 2006 amendments	12-Sep-2006	Partial	Innovator
Western	Calgary, AB	Land Use Bylaw 1P2007	23-July-2007	Partial	Early Adopter
Western	Ladysmith, BC	Bylaw No. 1691	1-Jun- 2009	Full	Early Adopter
Western	Comox, BC	Rezoning Application RZ 09–2; Bylaw No. 1636	21-Oct-2009	Partial	Early Adopter
Western	Mission, BC	Zoning Bylaw 5050–2009	30-Oct-2009	Full	Early Adopter
Western	Central Saanich, BC	Land Use Bylaw Amendment 1667	11-Jan-2010	Full	Early Adopter
Western	Beaumont, AB	Land Use Bylaw 796–12	23-Jan-2013	Partial	Early Adopter
Western	Nelson, BC	Zoning Bylaw No. 3199, 2013 (2014/019)	2-Feb-2014	Full	Early Adopter

[a]Eastern region includes the following provinces: Newfoundland & Labrador (NL), Prince Edward Island (PEI), Nova Scotia (NS), New Brunswick (NB), Québec (QC), and Ontario (ON). Western region includes: Manitoba (MB), Saskatchewan (SK), Alberta (AB), and British Columbia (BC). Not all provinces in each region had a ban at the time of this study. There was also no evidence of municipal drive-through bylaws in the northern territories (Yukon, Northwest Territories, and Nunavut)

in the western region of Canada (Table 1; Fig. 1). There were no adopters in the northern region of Canada at the time of the study. Accordingly, study findings are presented by region. The following sub-sections describe the chronological adoption of bylaws banning fast food drive-through services in municipalities, first in the eastern region of Canada, followed by adopters in the western region.

Eastern Canada

The first adoption of a fast food drive-through ban in Canada occurred in eastern Canada. In August 2002, Toronto, ON was the first municipality to formally adopt a bylaw to ban fast food drive-through services within the city [33]. In subsequent years, municipalities neighbouring Toronto, such as Markham, ON [34, 35], Ajax, ON [36], and Windsor, ON [37] adopted similar bans. Beginning in 2008, the cities of London and Kingston in Ontario both adopted fast food drive-through bans [38, 39]. This was quickly followed by the Ontario towns of Barrie [40] and Grimsby [31] in 2009 and 2010, respectively. Fast food drive-through bans continued over the next 5 years, with Niagara Falls, ON [41]; Hamilton, ON [42]; Halifax, NS [43] adopting bylaws in 2011. In 2012, Innisfil, ON [44, 45] and Caledon, ON [46] both adopted fast food drive-through bans. In 2013, another Atlantic city adopted a

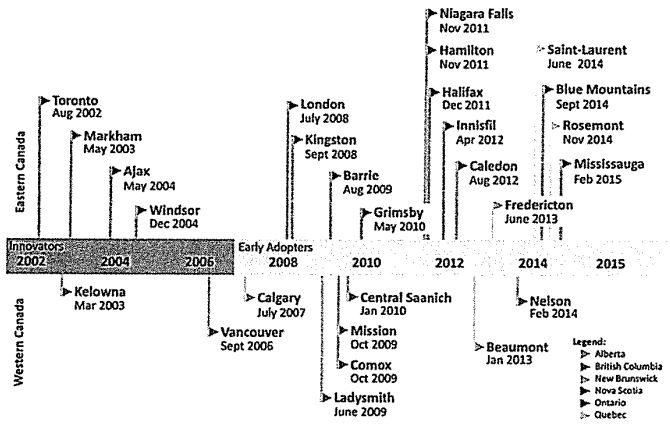

Fig. 1 Municipal bylaw fast food drive-through bans by date of adoption, municipality, province, region, and adopter-type

bylaw, this time in the City of Fredericton, NB [47]. Lastly, a proliferation of bylaw adoptions to ban fast food drive-through services was observed between 2014 and 2015. These included the borough of Saint-Laurent, QC [48, 49]; The Blue Mountains, ON [50, 51]; the borough of Rosemont-La-Petite-Patrie, QC [52]; and Mississauga, ON [53].

Western Canada

In western Canada, adoption of bylaws banning fast food drive-through services began with Kelowna, BC in 2003 [38] and the City of Vancouver, BC [39, 54] in 2006. Both municipalities amended their zoning and development bylaws in order to ban and restrict fast food drive-through services in their municipalities. Adoption of fast

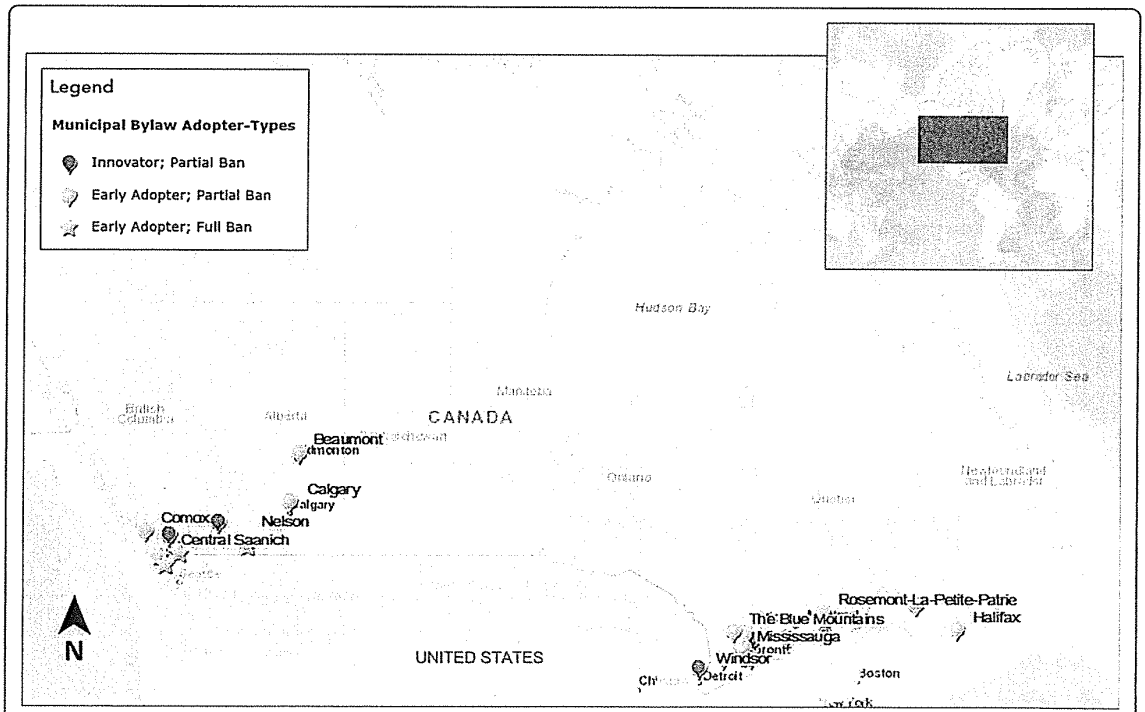

Fig. 2 Map of municipal bylaw adopters across Canada by adopter-type. Map source: Esri, HERE, Garmin, NGA, USGS | Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

food drive-through bans continued in western Canada spanning the provinces of British Columbia and Alberta. The first Albertan municipality to adopt a fast food drive-through ban was Calgary, AB [55] in 2007. Subsequently, the municipalities of Ladysmith [56], Comox [57], and Mission [58] in British Columbia each adopted bylaws in 2009, followed by the District of Central Saanich, BC in 2010 [59]. Most recently, in 2014 Beaumont, AB [60] and Nelson, BC [77, 78] succeeded in adopting fast food drive-through bans.

Extent of bans

Fast food drive-through service bans were categorized either as a 'full' or 'partial' ban based on the number of zones affected. A full ban categorized municipalities that banned fast food drive-through services across the entire municipality, while partial bans applied to one or more (but less than all) municipal zones. Our categorization of municipal bylaws revealed that 22 (81.5%) municipalities adopted a partial ban and five (18.5%) municipalities adopted a full ban (Table 1).

Intent of bans

We compared the purposes and rationalizations for fast food drive-through service bans and policies from our study to the intentions of similar policies as identified in the literature (Table 2). Study findings pertaining to bylaw intent aligned with eight of the 11 themes identified in the literature, with many bylaws covering multiple intentions. The intentions identified in our study that aligned with the literature include the following: protect community aesthetics and character; reduce traffic concerns and reduce dependency on automobiles; protect community comfort and safety; reduce physical inactivity and sedentary behaviour; protect local economy; address environmental concerns by reducing air pollution and idling; address noise concerns from intercoms; and promote community walkability, active transportation, and public transportation. Our study revealed four additional fast food drive-through bylaw intentions not found in the literature: improve urban design and promote downtown centres; promote sustainability and sustainable development; reduce odour and litter in neighbouring communities; and reduce visual impact of drive-through facilities, including lighting or sound encroachment in neighbouring communities. Of note, no municipalities identified in our study outlined 'obesity and chronic disease' as a reason to adopt a fast food drive-through service ban, although the literature identified this intent as the most common reason for a ban on fast food drive-through facilities.

Policy learning

Of the 27 adopters, nine municipalities (33.3%) undertook one or more policy learning strategies to inform

Table 2 Summary of intentions and rationales identified in the literature for adopting a zoning bylaw banning fast food drive-through services, compared to bylaw intentions identified in this study

Bylaw intentions identified in literature	Bylaw intentions identified in this study
Obesity and chronic disease [4, 5, 8–16]	Not identified
Protect community aesthetics and character [4, 5, 10–12, 17–19]	Protect community aesthetics and character ($n = 10$)
Traffic concerns [17–22]	Traffic concerns and reduce dependency on automobiles ($n = 10$)
Safety [5, 10, 19, 20, 22]	Community comfort and safety ($n = 4$)
Reduce physical inactivity and sedentary behaviour [5, 8, 14, 28]	Reduce physical inactivity and sedentary behaviour ($n = 1$)
Protect local economy [4, 5, 23]	Protect local economy ($n = 1$)
Improving community nutrition [5, 9, 13]	Not identified
Air pollution, idling, and environmental concerns [5, 18]	Air pollution, idling, and environmental concerns ($n = 9$)
Reduce inequalities by decreasing the density of fast food drive-through in low-income neighborhoods [5, 29]	Not identified
Noise concerns from intercoms [19, 30]	Noise concerns from intercoms, especially near residential areas ($n = 7$)
Improve community walkability [5]	Promote community walkability, active transportation, and public transportation ($n = 15$)
Not identified	Urban design, promote downtown core ($n = 10$)
Not identified	Sustainability and sustainable development ($n = 2$)
Not identified	Reduce odour and litter ($n = 1$)
Not identified	Reduce visual impact of drive-through and lighting/illumination encroachment, especially near residential areas ($n = 4$)

the process of adopting a bylaw banning fast food drive-through services. Policy learning was categorized as public consultation and/or research (local scan or on external policies). All nine municipalities that undertook one or more policy learning activities were characterized as early adopters, and none of the six innovator municipalities demonstrated evidence of performing policy learning activities. Of the nine early adopters that took action, six municipalities (66.7%) conducted both public consultation and research activities (local scan: $n = 5$; external research: $n = 1$). Of the remaining three, one municipality (11.1%) conducted only public consultation, and two (22.2%) conducted only research (local scan: $n = 1$; external research: $n = 1$) as part of their policy learning activities. There was no documented evidence of policy learning strategies utilized by the remaining 12 early adopter municipalities.

Discussion

This is the first study to examine municipalities across Canada that have adopted a zoning bylaw that bans fast food drive-through services. Over a 13-year period, very few municipalities across Canada have adopted a ban on fast food drive-through services. Of the adopters, we observed two parallel geographic patterns of fast food drive-through service ban adoptions: one in eastern Canada and one in western Canada. Densely populated municipalities within eastern Canada, namely the city of Toronto, ON, led the way with diffusion spreading the policy to surrounding municipalities. This finding aligns with the notion that innovators tend to be larger, more populous, and wealthier [61] than the typically lesser-populated jurisdictions in the early adopter and later adopter groups.

In western Canada, the pattern of diffusion was similar, with bylaw spread likely initiating with a partial ban adopted by Kelowna, BC (2003), and followed by partial bans in the densely-populated cities of Vancouver, BC (2006) and Calgary, AB (2007). However, it was the smaller municipalities in western Canada that were the first to adopt full fast food drive-through bans (Table 1). These findings are consistent with a previous study of US municipal fast food restaurant land-use regulations [4], which found that most adopter municipalities were of relatively small population size. Of the 77 municipalities included in the study, approximately 56% had a population of less than 20,000 people (and approximately 40% with a population of less than 10,000) [4]. These findings suggest that there may be benefits and facilitators beyond large population size and wealth that influenced the adoption of fast food drive-through services in some Canadian municipalities.

Awareness of adopter characteristics is critical to a complete understanding of how policies diffuse, particularly if one is seeking to leverage or enhance the policy cycle to achieve a particular policy outcome. Herein, we identified two of Rogers' five adopter-types [25]: innovators and early adopters. The remaining three adopter-types were not present at the time of study, likely due to the large number of potential adopters that have yet to adopt a fast food drive-through bylaw. Adopters of novel or emerging policies often do not include all five of Rogers' diffusion of innovations adopter-type categories, as adoption by all groups may take considerable time to fully play out [62].

According to Rogers' Diffusion of Innovations Theory [25], innovators tend to be more cosmopolite (i.e., larger urban or metropolitan areas), are more willing and often eager to try new ideas, have a greater threshold for risk, have a larger population with a wealth of resources, have extensive social networks, and are first to adopt a new innovation. In our study, innovators in eastern Canada were large cosmopolitan municipalities with many resources available to take risks with new innovations. However, in western Canada, there was a mix of population sizes among the innovators. This finding of varied diffusion patterns across Canada aligns with research on smoke-free policies in the provinces of Ontario and Alberta [62]. In both provinces, diffusion occurred both down hierarchies from larger, urban cities to less populated municipalities, and upwards from smaller centres to larger municipalities, with innovators representing a variety of population sizes.

Beyond innovators, Rogers characterizes early adopters as being more integrated within a local social system than innovators, making them localities [25]. To remain respected, early adopters must ensure that a judicious decision-making process is undertaken before adopting a new idea. In essence, the early adopter's role is to reduce the amount of uncertainty for other jurisdictions to facilitate adoption of an innovation [25]. Adoption of a new idea often involves a level of learning and understanding of whether a policy adopted elsewhere was successful [61]. This characterization aligns with the characteristics of the early adopter municipalities identified in our study, particularly in terms of the policy learning activities that were taken by this group. For example, over 40% of early adopters in the current study conducted research and/or public consultation activities, compared to none of the innovators. The early adopters were more informed during their decision-making process and considered some evidence prior to adoption. In addition, the early adopters did not copy previous bans, but rather used their policy learning strategies to implement a ban to fit the needs of their municipality.

Due to the emergent nature of this policy topic, we have yet to see how the early adopters may influence later adopter-types to move forward with a fast food drive-through ban. Research indicates that diffusion may

take a number of decades [62], and furthermore, may be delayed by what is known as a 'chasm' between the early adopter and early majority groups [63, 64]. The chasm describes the rapid adoption of innovations (in this case, fast food service drive-through bans), followed by a 'lull' as the innovation either is discontinued or evidence of its efficacy encourages adoption by the early majority adopter group [64]. The 'chasm' presents a timely opportunity for healthy public policy advocates to advance future policy adoption by assessing policy impact of extant policies and actively disseminating findings of policy efficacy to potential early majority adopter municipalities.

The focus of our study was to identify and characterize current adopters of municipal fast food drive-through service bylaws in Canada. Beyond the 27 municipal adopters, we also identified two groups of non-adopters: those who attempted to adopt a ban and failed; or those who were currently in the process of bylaw adoption. Similarly, a study of US bylaws regulating fast food restaurants and drive-through services in the United States found that of the 100 included policies, 63 were enacted, five were enacted and then later repealed, and 32 were raised in council but were not passed [4]. It is therefore important to understand the reasons why some municipalities were unsuccessful with their policy efforts, as well as understand why others may take longer to adopt.

Examples of Canadian municipalities that attempted to adopt a bylaw, but failed include Squamish, BC and Côte-des-Neiges—Notre-Dame-de-Grâce, QC. In both cases, the municipality was undertaking the bylaw development process around the same time as nearby successful adopters. However, due to involvement from opposition groups, such as the Restaurants Canada (formerly known as Canadian Restaurants & Foodservices Associations (CRFA)), both municipalities failed to adopt a bylaw [65, 66]. Although this study may not capture all reasons for failure to adopt, other identified reasons found in the study data included competing policies or alternate directions (e.g., anti-idling bylaws) and/or lack of political support. Further investigation of failed attempts to adopt fast food drive-through services bans may help those interested in such a policy to address the identified barriers, better engage with key stakeholders, and inform decision-makers of the policy change efforts already put forward. Together, these actions may ignite commitment to persist in successful adoption.

At time of this study, there was evidence that four municipalities were in the process of adopting a ban. For example, Waterloo, ON has included regulations on fast food drive-through service development as part of their Official Plan [67], with zoning bylaw amendments yet to be adopted, but anticipated. Similarly, in February 2016 the municipal council of the Corporation of Delta, BC adopted a recommendation from the Community Planning Advisory Committee that the municipality develop guidelines and/or a policy relating to drive-through facilities [68]. These examples indicate that drive-through service bylaws and policies continue to be of focus in some municipalities across Canada. Furthermore, these potential adopter municipalities may represent early majority adopter-types, as per diffusion of innovations theory. These groups require more time to research their options, get buy-in from municipal decision-makers, and likely require evidence of successful adoption in other, similar jurisdictions before choosing to adopt a policy. It will be important for public health researchers and policy makers to track the progress of these majority group adopters as diffusion continues.

Also important are those municipalities that have adopted design guidelines or regulations to determine where drive-through services may be located and what design requirements they must meet. The City of Ottawa, Ontario, for example, developed urban design guidelines for drive-through facilities in 2006 [69]. Similarly, the City of St. John's, NFLD developed drive-through facility regulations in 2012 that required all applications for a drive-through to be reviewed and approved by the city before development [70]. Unfortunately, many of the guidelines and plans do not have legal grounding, like that of a bylaw, and thus may not be fully enforced. These examples of guidelines and regulations are evidence that municipalities are taking action towards addressing an issue, but also demonstrates that municipalities such as these are not able or willing to adopt a more permanent, enforceable policy. These municipalities may only adopt a formal ban once the benefits of the policy clearly outweigh the risks, or after a large proportion on municipalities across Canada adopt fast food drive-through service bylaws. Further, considerations of issue framing are important: while health promotion and chronic disease prevention are public health gains from the implementation of fast food drive-through service bylaws, none of the successful adopters outlined this as part of their rationale for their bylaws. These cases have demonstrated that it may not be necessary to invoke a health frame in order to realize municipal healthy public policy.

Strengths and limitations

To our knowledge, this study is the first to explore the adoption and diffusion of bans on fast food drive-through services in municipalities across Canada. While zoning and land-use bylaws banning fast food restaurants and drive-through services have been studied in the United States [4, 5, 12, 13, 15], there has been limited research

conducted in the Canadian context. Our contribution to the literature may be useful to public health departments and local governments seeking to employ zoning bylaws, restrictions, and/or policies as a strategy to foster healthy food environments.

Application of the diffusion of innovations theory [25] was a useful framework in describing the spread of adoption of bylaws through adopter categories. This is novel as, to date, the diffusion of innovations theory framework has not previously been applied to the literature on zoning bylaws to address health outcomes. This may inspire future work in this area as an increased understanding of how policies spread is crucial to study healthy public policy adoption.

This study was limited to by the relative short period of policy activity (i.e., since 2002): currently, only innovator and early adopter categories were captured. As this policy issue continues to emerge, public health actors and other stakeholders can utilize the growing momentum to employ scholarly methods, such as longitudinal and case control studies, in an effort to better understand the adoption, spread, and impact of bylaws banning fast food drive-through services over time and across jurisdictions. Further, assessment of policy effectiveness, while beyond the scope of this study, is required to determine the viability of fast food drive-through bans strategy for health promotion and chronic disease prevention.

The short period of policy activity and limited number of adopters to date were also contributing factors to limitations in study design. For instance, the methods employed were constrained by the number of adopter municipalities. Our determination of adopter-types was based on the clustering of adoption dates and alignment with broad definitions for each adopter-type, rather than an empirical fit to Rogers' diffusion S-curve [25], which was not possible with such a small number of adopters. Consequently, policy diffusion analysis and justification for adopter-type categorization becomes challenging when subjective constraints are present. However, this novel approach to characterizing adopter-types may be of merit for future research to develop a qualitative protocol for adopter-type characterization based on Rogers' diffusion of innovations theory. Another possible solution to this limitation would be to re-examine this policy at a later point in time once more municipalities have adopted a fast food services drive through bylaw, or when related policy options emerge.

As policy adoption is on-going in nature, our list of adopters is inclusive only up to when data analysis occurred, and characterization of those adopters relative to others in the community or network of adopters may be subject to change over time. If examined again in another decade or two, and assuming continued adoption of this policy leading to a greater number of adopters, it is possible that those municipalities categorized as early adopters at this point in time may actually be seen as innovators relative to the rest of the adopters in the community. Further, investigation of the factors that influenced the diffusion of fast food services drive-through bylaws (e.g., policy opportunity windows, geographical location, and political climate) were beyond the scope of this study. However, such diffusion and contributing factors could be the foci of future studies.

Conclusions

This is the first study to examine municipalities across Canada that have adopted a zoning bylaw that bans fast food drive-through services. This policy diffusion study detailed the chronological history, geographical patterns, and adopter characteristics of Canadian municipalities with fast food drive-through bans. The characterization of the adopter municipalities, along with the nature of the bylaw adopted, contributes a fuller understanding of the factors associated with bylaw adoption. In addition, while the policy cycle can be a complex and arduous process, this study demonstrated the utility of policy learning, as a characteristic of policy diffusion, to support the adoption of fast food drive-through bans. Municipalities motivated to adopt a fast food drive-through bylaw ban enhanced their policy development cycle by utilizing previously developed policy drive-through bylaw bans in similar jurisdictions, thereby saving time and resources.

Our study findings revealed a limited number of adopter municipalities, suggesting that policy diffusion of zoning bylaws for drive-through bans is still an emerging process. Further, as policy diffusion is in its infancy with regards to bans utilizing zoning bylaws, evaluations of current policies are required to examine the impact and effectiveness of bylaws banning drive-through services on population health and other indicators of interest to communities (e.g., economic or environmental outcomes).

Overall, the implications for research and practice in zoning bylaws for drive-through services are evolving and dynamic. Fast food drive-through service bans are one policy option that may be considered as part of a comprehensive, multi-pronged strategy to promote healthier food environments and improve population health. Research in the area of healthy food environments and zoning bylaw utilization may prove to be a vital part of preventing chronic disease in Canada.

Abbreviations

AB: Alberta; BC: British Columbia; NB: New Brunswick; NS: Nova Scotia; ON: Ontario; QC: Québec; US: United States of America

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Availability of data and materials
The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations
None

Authors' contributions
CIJN: study design, analysis, interpretation, manuscript development; EJC: study design, data collection, analysis, interpretation, manuscript development; SM: study design, data collection, analysis, interpretation, manuscript development; DM: manuscript development; KA: edited the manuscript; interpretation. KDR: study design, edited the manuscript; All authors read and approved the final manuscript.

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Research Article Open Access

An Evaluation of the Effects of Drive-Through Configurations on Air Quality at Fast Food Restaurants

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Abstract

Drive-thru users at fast food restaurants stay in their vehicle and have the engine running instead of walking into the restaurant to place an order for food or beverage. Although the drive-thrus are convenient, and they save time for costumers, they may have negative impacts on the air quality. Idling vehicles waiting in lines at drive-thru facilities waste gas, harm air quality, and increase greenhouse gas emissions. This study examined the emission rates at three fast food restaurants in Houston, TX, with different drive-thru configurations. By driving on each drive-thru facility in two different times of the day (peak hours and non-peak hours), instantaneous speed and acceleration of vehicles were collected on a second-by-second basis using Global Positioning System (GPS) devices. Then, for each second-by-second data, Vehicle Specific Power (VSP) value was calculated using instantaneous speed and acceleration. VSP and instantaneous speeds of the vehicles were used to obtain the operating mode distribution bins according to the standard provided by the Motor Vehicle Emission Simulator (MOVES). The vehicle emissions were calculated based on the operating mode binning approach. Emission factors analyzed in this study are Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxides of Nitrogen (NO_x), and Hydrocarbons (HC). The results of the study showed that the estimated emission is lower at drive-thru facilities with fewer stops and number of lanes.

Keywords: Drive-thru; Emission; Operating mode; Vehicle Specific Power (VSP)

Introduction

With the fast food restaurant business consistently growing, it causes more and more people to use the drive-thru facilities, especially in the big cities where time and convenience are major factors in the daily activities of people. The drive-thru facilities have increasingly become an integral part of not only the fast food restaurants, but also the other businesses such as banks, DVD rentals, ATMs, coffee shops, pharmacies, and dry cleaners. In general, drive-thru windows are very popular convenience for those people who drive. Although drive-thrus are convenient, and they save time for customers; they may have negative impacts on the air quality. In this study, three fast food restaurants in Houston, TX, with different drive-thru configurations will be examined, and the total emissions associated with their drive-thru facilities will be estimated.

Background

Most of the people living in major cities prefer to use the quickest and easiest way when it comes to ordering their food at fast food restaurants. Drive-thru shopping has become a part of their daily routine where their vehicles are kept idling during the service period. No matter whether there are lines inside of the restaurant and how many vehicles are waiting in the drive-thru line, drivers never step out their vehicle to make an order insider of the restaurant. However, such an idling behavior may result in enormous health and environmental consequence. A significant number of byproducts of burning fossil fuel may be produced during idling, which include carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), and Volatile Organic Compounds (VOC). While CO_2 as a greenhouse gas contributes the most to global warning [1], CO, NO_x and VOC are toxic exhaust gases for humans. Further, NOx can react with VOC and still air under sunlight to form toxic smog. Meanwhile, NOx is associated with the formation of acid rain. The concentration of the four byproducts in the exhaust gases is highly subject to many factors, such as vehicle operation [2], pavement types and roughness, engine efficiency, and roadway design [3, 4]. For example, CO concentration in the exhaust gases is the highest during an idling phase with 69, 000 ppm from a gasoline engine [5]. Vehicle emissions could be reduced at traffic conflicting areas, such as work zones [6,7], and signalized intersections in fog [8], where are equipped with Vehicle to Infrastructure (V2I) to improve drivers' driving behaviors [9].

According to a published statistics in 2010, "drive-thru sales account for more than 60% of McDonald's overall revenues. Burger King relies on drive-thrus for 62% of its revenues. For Wendy's, the number is about 60%. Starbucks doesn't break out drive-thru revenues, but the chain operates approximately 2,650 drive-thru locations, representing approximately 35% of company-operated stores in the USA and Canada combined" [10]. This statistics reveals there is a high proportion of population nationwide using the drive-thru facilities daily. It seems that drivers' convenience has been trading off by air quality and public health.

Some local governments have adopted policies in this issue and launched anti-idling campaigns to help educate people about negative impacts of idling on the environment. Furthermore, there are growing debates about the environmental impact of drive-thrus [11-15] and a few governmental agencies have been trying to eliminate and ban drive-thrus. The USA Federal Highway Administration (FHWA) recommends turning off the vehicle engines in drive-thrus to reduce emissions and climate change [16]. However, most people do not know that a vehicle that is idle at a drive-through facility and wait for a long period of time produces a considerable amount of emission. The USA Environmental Protection Agency (EPA) presented tables including idle emission factors for volatile organic compounds (VOC), carbon monoxide (CO), and oxides of nitrogen (NO_x) for both summer and winter conditions [17]. Idle emissions for particulate matter (PM10) were also provided for heavy-duty diesel vehicles only since it was negligible for gasoline-

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fueled vehicles. EPA suggested use of the idle emission factors to obtain first-order approximations of emissions under idle conditions. There are few studies on the estimation of emission at drive-thru facilities. A group of college students in Pennsylvania calculated the vehicle emissions at two fast food restaurants by counting the vehicles and using an equation provided by EPA office of mobile sources [18]. Mittingly et al. developed a methodology for estimating benefits associated with drive-thru restrictions by characterizing a drive-thru as an M/M/1 queuing system, and calculated the reduction in NO_x emissions [19].

As having been noticed, drive-thru facilities at fast food restaurants are built differently in terms of their configurations (number of stops, number of lanes, etc.); however they all serve the same purpose. This study will examine the emission rates at three fast food restaurants in Houston, TX, with different drive-thru configurations.

Materials and Methods

Vehicle Specific Power (VSP) is a well-accepted explanatory variable in microscopic emission modeling. VSP is defined as the instantaneous tractive power per unit vehicle mass [20]. The main advantages of using VSP as an independent variable for studying the stabilized emissions of passenger cars and light-duty trucks are: it can be directly calculated from roadside measurements, it captures most of the dependence of emissions on engine operating parameters, and certification driving cycles are defined as a speed versus time trace and can also be specified in terms of VSP. The commonly used unit of VSP is Kw/Metric Ton. VSP distributions not only represent well the driving characteristics but also are highly correlated with the vehicle emission characteristics [21-23]. VSP is calculated using the following equation [20]:

$$VSP = v \times [1.1\, a + 9.81 \times grade\ (\%) + 0.132] + 0.000302\, v^3 \quad (1)$$

where:

v is the vehicle speed (m/s),

a is the vehicle acceleration (m/s^2), and

grade (%) is the vehicle vertical rise divided by slope length.

Since the data collection area was flat, the grade was zero in Equation (1). Therefore, the equation can be simplified as:

$$VSP = v \times (1.1\, a + 0.132) + 0.000302\, v^3 \quad (2)$$

VSP-based emission modeling approaches have been used to quantify a vehicle's emissions during its regular operations [24-26]. The basic methodology for this modeling approach is binning second-by-second VSP data and computing the average emission rate in each bin. The meaning of each bin is the percentage of corresponding VSP values in the whole distribution. With this partition, the average emission rate of a particular type of pollutant in that bin for a specific vehicle can be calculated. The accuracy of the VSP-based modeling approach relies on how VSP bins are defined. There has been no clear definition about criteria in selecting VSP cutting points. However, since Motor Vehicle Emission Simulator (MOVES) is currently considered the standard tool that the USA Environmental Protection Agency has for estimating greenhouse gas (GHG) emissions from transportation sector, the definition of VSP bins provided by MOVES is used in the binning process in this study. Operating mode bins are a categorization method that describes vehicle behaviors based on the instantaneous speed and VSP characteristics, which serves the primary tool when generating total emissions [27,28]. Table 1 illustrates details of the operating mode binning provided by MOVES. In the table, the Operating Mode ID refers to operating mode bins that represent braking, idling, and varying levels of the vehicle's VSP and speed. The operating mode bins are broken down into 23 bins that range from 0 to 40. As shown in the table, bins 0 and 1 represent braking and idling. Bins 11 to 16 represent

Operating Mode ID	Operating Mode Description	Vehicle Specific Power, VSP_t (kW/tonne)	Vehicle Speed, v_t (mph)	Vehicle Acceleration, a_t (mph/sec)
0	Braking			($a_t \le -2$) or ($a_t \le -1$ and $a_{t-1} \le -1$ and $a_{t-2} \le -1$)
1	Idling		$-1 \le v_t < 1$	
11	Low Speed Coasting	$VSP_t < 0$	$1 \le v_t < 25$	
12	Cruise/Acceleration	$0 \le VSP_t < 3$	$1 \le v_t < 25$	
13	Cruise/Acceleration	$3 \le VSP_t < 6$	$1 \le v_t < 25$	
14	Cruise/Acceleration	$6 \le VSP_t < 9$	$1 \le v_t < 25$	
15	Cruise/Acceleration	$9 \le VSP_t < 12$	$1 \le v_t < 25$	
16	Cruise/Acceleration	$12 \le VSP_t$	$1 \le v_t < 25$	
21	Moderate Speed Coasting	$VSP_t < 0$	$25 \le v_t < 50$	
22	Cruise/Acceleration	$0 \le VSP_t < 3$	$25 \le v_t < 50$	
23	Cruise/Acceleration	$3 \le VSP_t < 6$	$25 \le v_t < 50$	
24	Cruise/Acceleration	$6 \le VSP_t < 9$	$25 \le v_t < 50$	
25	Cruise/Acceleration	$9 \le VSP_t < 12$	$25 \le v_t < 50$	
27	Cruise/Acceleration	$12 \le VSP_t < 18$	$25 \le v_t < 50$	
28	Cruise/Acceleration	$18 \le VSP_t < 24$	$25 \le v_t < 50$	
29	Cruise/Acceleration	$24 \le VSP_t < 30$	$25 \le v_t < 50$	
30	Cruise/Acceleration	$30 \le VSP_t$	$25 \le v_t < 50$	
33	Cruise/Acceleration	$VSP_t < 6$	$50 \le v_t$	
35	Cruise/Acceleration	$6 \le VSP_t < 12$	$50 \le v_t$	
37	Cruise/Acceleration	$12 \le VSP_t < 18$	$50 \le v_t$	
38	Cruise/Acceleration	$18 \le VSP_t < 24$	$50 \le v_t$	
39	Cruise/Acceleration	$24 \le VSP_t < 30$	$50 \le v_t$	
40	Cruise/Acceleration	$30 \le VSP_t$	$50 \le v_t$	

Table 1: Definition of MOVES operating mode characteristics [17].

Operating Mode ID	CO_2 (g/s)	CO (mg/s)	HC (mg/s)	NO_x (mg/s)
0	0.89	1.83	0.85	1.3
1	0.75	0.84	1.04	1.71
11	1.08	3.9	1.49	1.3
12	1.84	8.19	2.77	2.38
13	3.44	22.41	4.24	3.97
14	4.6	22.04	7.04	5.72
15	5.67	23.11	7.51	9.92
16	6.83	32.4	2.72	18.25
21	1.25	2.57	1.38	1.93
22	1.97	3.51	3.94	2.36
23	2.83	6.65	4.72	4.59
24	3.92	9.31	3.51	6.55
25	4.87	9.65	3.39	10.49
27	6.3	12.51	5.31	20.28
28	7.41	11.17	9.26	31.05
29	7.89	11.35	14.09	35.42
30	5.17	13.74	2.35	11.5
33	2.46	4.11	1.64	3.47
35	4.56	9.25	1.92	7.11
37	5.68	10.51	4.24	13.05
38	6.64	9.82	3.98	18.99
39	7.44	18.68	5.66	28.62
40	5.20	9.03	4.74	13.09

Table 2: Emissions rates of operating mode bins collected with PEMS [18].

driving behavior with lower speeds. Bins 21 to 30 represents driving behavior between 25 mph to 50 mph. Bins 33 to 40 represents driving behavior with speed 50 mph and greater.

In this study, VSP values will be calculated using instantaneous speed and acceleration data collected by GPS devices. Once VSP is determined, the data can be categorized using the operating mode binning approach. Then, the vehicle emissions can be calculated based on the operating mode binning approach. Tao and Yu [29] conducted a research study and determined the emission rates in each operating mode bin using the real emission data of a light-duty vehicle collected by a Portable Emission Measurement System (PEMS). Those emission rates are shown in Table 2. Therefore, the total emissions can be calculated by combining the emission rates in Table 2 and the operating mode bins. Emission factors analyzed in this study are Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxides of Nitrogen (NOx), and Hydrocarbons (HC).

Data Collection

In this study, three fast food restaurants with different locations were selected in Houston, TX for data collection. When choosing the restaurants, the following considerations were taken into account:

- Location of restaurant
- Size of facility
- Number of existing lanes in drive-thru
- Number of stops in drive-thru

The data collection was conducted at each restaurant during the peak hours and non-peak hours. The location of the restaurants was important since the facilities should have been quite busy during the peak hours compared with non-peak hours. The first restaurant (Restaurant A) was located in a residential neighborhood, next to a large shopping center. The second restaurant (Restaurant B) was located in the area close to Texas Medical Center. The third restaurant (Restaurant C) was located close to two university campuses: Texas Southern University and University of Houston.

Before starting the data collection, each location was visited at different times of the day in order to determine the exact time for both peak hour and non-peak hour data collection. Finally, two time periods were selected: 11:00 a.m. to 1:00 p.m. as peak hours, and 2:30 p.m. to 4:30 p.m. as non-peak hours. For each restaurant, one graduate student with more than three years of driving experience was assigned to collect data during both peak hours and non-peak hours by driving his/her light-duty vehicle in the restaurant drive-thru. The fuel type for the vehicles was gasoline. In total, three drivers participated in data collection. The speed and acceleration were collected while driving in the drive-thru facilities using the portable Global Positioning System (GPS) devices (Figure 1). This data collection approach recorded second-by-second real-world driving behaviors. The drivers were advised to turn on the GPS device when they pulled into the driveway of the restaurants. They placed their order and continue driving through the drive-thrus like a regular costumer. The GPS devices were turned off after they pulled out of the drive-thru.

Each location had a different drive-thru configuration. The drive-thru at Restaurant A included two lanes with two stops. The first stop was at ordering station where the menu board was located between the lanes; and the vehicles could stop at this point and order their food. Then those two lanes eventually merge into one single lane where the customers could pay and pick up their order at the same window (Figure 2). Since the drive-thru was not very busy in the afternoon between 2:30 p.m. and 4:30 p.m., the right lane was closed during non-peak hours. Drive-thru configuration at Restaurant B was much more different compared to

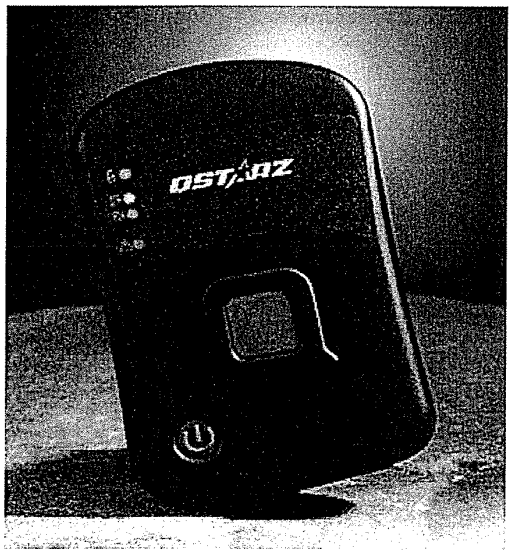


Figure 1: GPS device used to collect data in the drive-thru facilities.

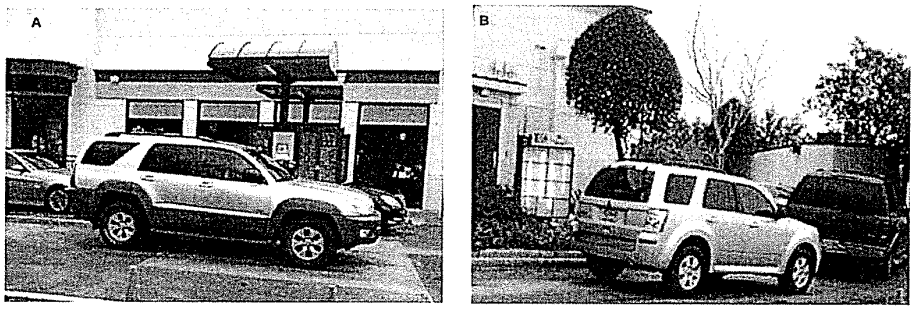


Figure 2: Drive-thru at Restaurant A: (a) the menu board (ordering station) located between two lines of vehicles, (b) the vehicles merging into one lane towards the pick-up window.

Figure 3: Drive-thru at Restaurant B: (a) the menu board (ordering station) with one lane vehicles, (b) payment and pick-up windows.

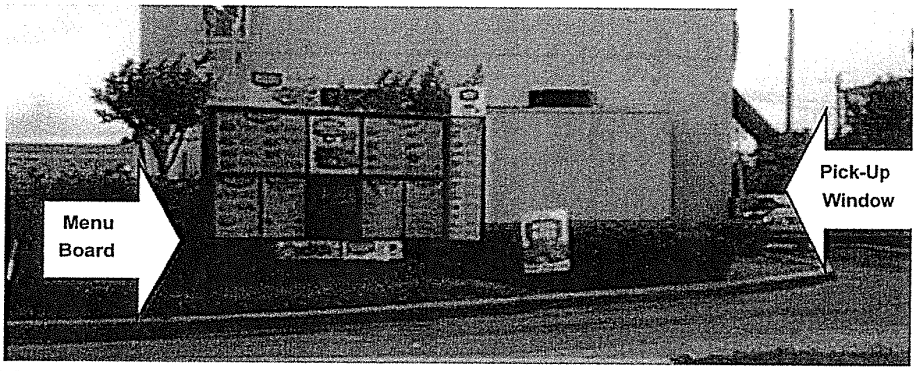


Figure 4: Drive-thru at Restaurant C: the menu board (ordering station) with one lane vehicles, and the window for payment and picking up the orders.

Drive-Thru		Peak Hours	Non-Peak Hours
Restaurant A	Left Lane	65 veh	52 veh
	Right Lane	80 veh	
Restaurant B		86 veh	32 veh
Restaurant C		49 veh	31 veh

Table 3: Traffic count at drive-thru facilities during both peak and non-peak hours.

Restaurant A. This facility had one lane with three stops. The first stop was to place the order, second stop was at the payment window where customers paid for their purchase, and the third stop was to pick up their food or beverage at the pick-up window (Figure 3).

The drive-thru facility at Restaurant C was similar to Restaurant A with the only difference in the number of the lanes. The facility had one lane with two stop. The first stop was next to the menu board where the drivers placed the order; and the second stop was at the pick-up window where they could pay and pick up their order (Figure 4). During data collection, there were other students who assisted in counting the traffic at drive-thru facilities at peak hours and non-peak hours. At each of Restaurants B and C locations, two students were assigned to record the data; the first student recorded the information when the vehicles were entering the drive-thru, and the second one recorded the same information when the vehicles were leaving. At Restaurant C location, only one student recorded the information since he had a good view of the entrance and the exit of the drive-thru. The information included the time the vehicles entered the drive thru, the time the vehicles left the drive-thru, the last four digits of the vehicles' license plates, and the vehicle type. Recording the time was necessary in order to calculate the presence time (waiting time) of each vehicle in the drive-thru facilities.

Table 3 shows the traffic count at each location. Traffic count indicates that more vehicles use the drive-thru facilities during peak-hours. As mentioned before, the right lane of the drive-thru facility at Restaurant A was closed at non-peak hours due to the fact that it was not as busy as during peak hours. Second-by-second data were collected using GPS devices (loggers). GPS loggers record the local time and date, longitude and latitude, and speed in kilometers per hour. Data processing followed the data collection phase of this study. The steps of this process are provided as follows:

Step 1: GPS data from the vehicles were used to calculate VSP for each second of data recorded using Equation (2).

Step 2: VSP and instantaneous speeds of the vehicles were used to obtain the operating mode distribution bins according to the standard in MOVES (Table 1).

Step 3: The operating mode bins were combined with the emission rates provided in Table 2, and the total emissions are estimated.

Results

The goal of this study was to analyze the effects of drive-thru facilities at fast food restaurants on emission outputs of light-duty vehicles. Real world GPS data was collected for three restaurants with different drive-thru configurations during peak hours and non-peak hours. The emission factors estimated were carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), and hydrocarbons (HC).

Figure 5 shows the operating mode distributions for the vehicles using the drive-thru facilities during non-peak hours (2:30 p.m. to 4:30 p.m.). As seen in the figure, Restaurant A has higher frequencies

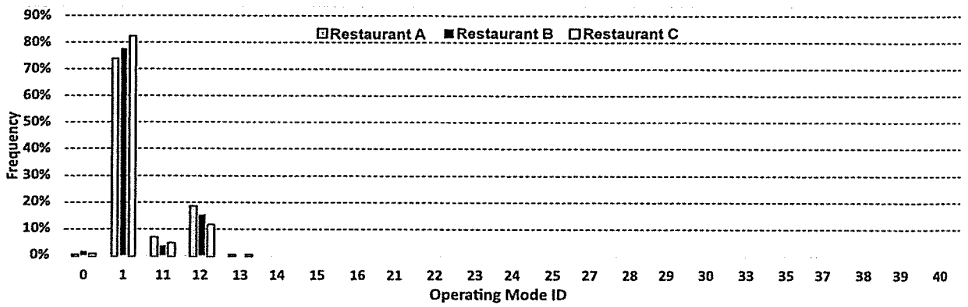
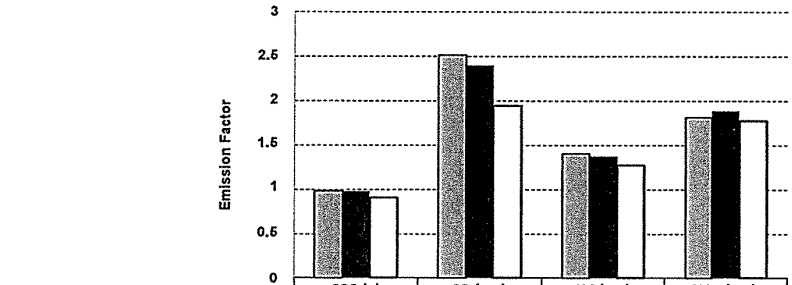


Figure 5: Operating mode distributions during non-peak hours.



	CO2 (g)	CO (mg)	HC (mg)	NOx (mg)
Restaurant A	0.986658711	2.510190931	1.403436754	1.813579952
Restaurant B	0.985894428	2.39973607	1.373577713	1.882258065
Restaurant C	0.905411765	1.941058824	1.275764706	1.775176471

Figure 6: Emissions during non-peak hours.

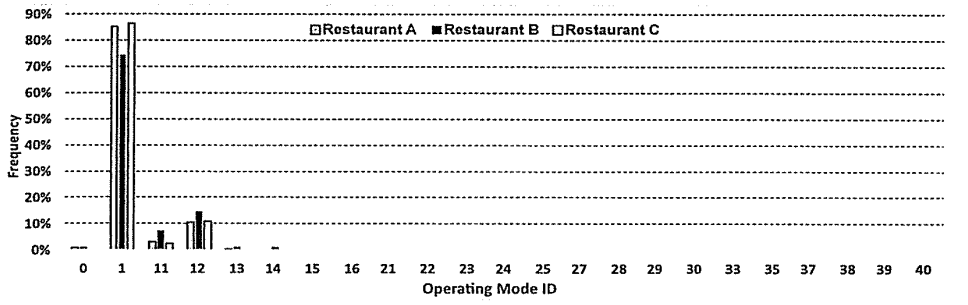
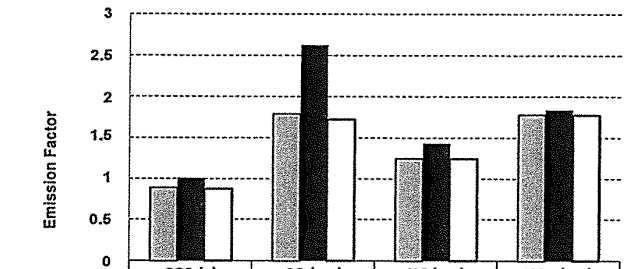


Figure 7: Operating mode distributions during peak hours.

in bins 11 and 12. These bins are described as low speed coasting and cruise/acceleration, respectively. However, it has lower frequency in bin 1 compared to the other two locations, that is idling. Figure 6 shows the emission factors for each light-duty vehicle using the drive-thru facilities during non-peak hours. During this time, Restaurant A had the highest emission factors except for NO_x. As mentioned above, the operating mode bins 11 and 12 of Restaurant A had higher frequencies, which could be the reason that the total emission for Restaurant A is higher than the other two restaurants (the emission rates of the operating mode bins 11 and 12 in Table 2 are higher than bin 1). Restaurant C has the lowest frequency in bin 12 but the highest in 1 indicating there were more idling during non-peak hours. Restaurant B in bin 12 is the second highest and it also the second highest for total emissions (except for NO_x). Figure 7 displays the frequencies of the operating mode bins for the vehicles using the drive-thru facilities during peak hours (11:00 a.m. to 1:00 p.m.). The frequency of the operating mode bin 1 (idling mode) for Restaurant A during peak hours is higher (74%) compared with the frequency of the bin 1 during non-peak hours (85%). That was because both lanes of the drive-thru facility at Restaurant A was open at non-peak hours, and two lanes had to merge into one single lane. In other words, the vehicles had to be idle for longer time. During the peak hours Restaurant B had the lowest idling time (bin 1), but higher



	CO2 (g)	CO (mg)	HC (mg)	NOx (mg)
Restaurant A	0.885793037	1.791005803	1.247021277	1.773017408
Restaurant B	1.007663043	2.62701087	1.426032609	1.840815217
Restaurant C	0.877925072	1.72426513	1.241123919	1.772737752

Figure 8: Emissions during peak hours.

frequencies in bin 11 and 12 compared with the other two locations (Figure 6). Furthermore, the drive-thru at Restaurant B has the highest emissions for all the emission factors. The reason is the drive-thru facility at this location has three stops (Figure 8).

Conclusion

This study examined the emission rates at three fast food restaurants in Houston, TX, with different drive-thru configurations. By driving on each drive-thru facility in two different times of the day (peak hours and non-peak hours), instantaneous speed and acceleration of vehicles were collected on a second-by-second basis using Global Positioning System (GPS) devices. Then, for each second-by-second data, VSP value was calculated using instantaneous speed and acceleration. VSP and instantaneous speeds of the vehicles were used to obtain the operating mode distribution bins according to the standard provided by the MOVES. The vehicle emissions were calculated based on the operating mode binning approach. Also, traffic count was conducted at each location. Traffic count indicated that more vehicles used the drive-thru facilities during peak-hours. Emission factors analyzed in this study are Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxides of Nitrogen (NO_x), and Hydrocarbons (HC). The results of the estimated emission in this study may seem to be relatively small (since it is related to a single vehicle), but it adds up when it is multiplied by all the vehicles idling at that specific drive-thru restaurant. Furthermore, the results showed that the total emission for a single vehicle using a drive-thru facility is not only related to the idling situation, but the other modes (bins 11 and 12) also have impact on the overall emission.

There are some other factors that must be taken into consideration when estimating the emission for a vehicle running in the facilities with the situation of idling and stop-and-go. One of the factors is number of the vehicles using the facility during that specific time period. This number not only has effect on the total emissions produced by all the vehicles, but it also has effect on the emission produced by that specific single vehicle. The reason is the average waiting time for each vehicle would be longer when there are more vehicles using the facilities. Therefore, it is very important to conduct the traffic count in these types of facilities.

Restaurant A location had the most traffic during peak and non-peak hours. The emissions were higher at this facility during non-peak hours versus peak hours. The reason was one of the lanes in the drive-thru facility was closed during non-peak hours, however the number of the vehicles using the drive-thru between 2:30 p.m. and 4:30 p.m. was still high (Table 3). Due to this fact, the waiting time was increased, and vehicles emitted more pollutions. During the peak hours, Restaurant B had the highest emission rate, since the drive-thru facility had three stops. As stated earlier, vehicle idling produces more emission and with each vehicle stoping at each window it causes more idling time. The result of the study shows that Restaurant C seems to have the best drive-thru configuration (one lane, two stops) since the related emission factors was the lowest during both non-peak hours and peak hours. At Restaurant C drive thru, there were not as many stops and lanes like Restaurants A and B. Therefore, there was less idling time for the vehicles. It seems that designing the restaurant drive-thrus with one lane and two stops may decrease of the vehicle emissions comparing to other design configurations.

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