ADD-ONS

ADD-ONS

COUNTY COUNCIL OF BEAUFORT COUNTY
ADMINISTRATION BUILDING
BEAUFORT COUNTY GOVERNMENT ROBERT SMALLS COMPLEX
100 RIBAUT ROAD
POST OFFICE DRAWER 1228
BEAUFORT, SOUTH CAROLINA 29901-1228
TELEPHONE: (843) 255-2180
www.bcgov.net

AGENDA
NATURAL RESOURCES COMMITTEE

Monday, September 18, 2017
4:00 p.m.
Executive Conference Room, Administration Building
Beaufort County Government Robert Smalls Complex
100 Ribaut Road, Beaufort

Committee Members:
Brian Flewelling, Chairman
Roberts "Tabor" Vaux, Vice Chairman
Rick Caporale
Gerald Dawson
Steve Fobes
York Glover
Alice Howard

Staff Support:
Anthony Criscitiello, Planning Director
Gary James, Assessor
Eric Larson, Division Director
Environmental Engineering
Dan Morgan, Division Director
Mapping & Applications

1. CALL TO ORDER – **4:00 P.M.**

2. DISCUSSION / PREVIOUS PLANNING COMMISSION MEETING

3. PRESENTATION / SOUTHERN BEAUFORT COUNTY CORRIDOR BEAUTIFICATION BOARD

4. AN ORDINANCE OF BEAUFORT COUNTY COUNCIL CREATING A SPECIAL TAX ASSESSMENT FOR REHABILITATED HISTORIC PROPERTIES IN THE GEOGRAPHICAL BOUNDARIES KNOWN AS DAUFUSKIE ISLAND (backup)

5. DISCUSSION / DETERMINE DATES AND PLACES FOR MEETINGS TO RECEIVE PUBLIC COMMENT AND INPUT INTO POLICIES FOR AN ORDINANCE TO DEAL WITH PLASTIC BAGS AND A SUBSTITUTE FOR THEM WITH REUSABLE RETAIL CARRYOUT BAGS IN THE UNINCORPORATED AREAS OF BEAUFORT COUNTY

6. TEXT AMENDMENT TO THE COMMUNITY DEVELOPMENT CODE (CDC): SECTION 3.1.70 LAND USE DEFINITIONS, AGRICULTURE (TO ADD THE AQUAPONICS USE TO AGRICULTURE AND CROP HARVESTING LAND USE TYPE); APPLICANT: EDWARD D. KREBS (backup)

7. TEXT AMENDMENT TO THE COMMUNITY DEVELOPMENT CODE (CDC): ARTICLE 4, SECTION 4.2.20 GENERAL STANDARDS AND LIMITATIONS, T3-NEIGHBORHOOD (TO ALLOW PRIVATE FISH PONDS); APPLICANT: GREG HUMPHRIES (backup)

8. TEXT AMENDMENTS TO THE COMMUNITY DEVELOPMENT CODE (CDC), ARTICLE 5 (SUPPLEMENT TO ZONES), DIVISION 5.5 (OFF-STREET PARKING), SECTION 5.5.30.A. STORAGE AND/OR PARKING OF HEAVY TRUCKS AND TRAILERS (backup)

9. DISCUSSION ONLY / SHERIFF P.J. TANNER / COUNTY ADMINISTRATOR GARY KUBIC / DIGITAL MESSAGING COMMUNICATION SYSTEMS

10. CONSIDERATION OF REAPPOINTMENTS AND APPOINTMENTS
    A. Southern Beaufort County Corridor Beautification Board

11. ADJOURNMENT

<u>2017 Strategic Plan Committee Assignments</u>
Hilton Head National Rezoning/Development Agreement
Priority Investment – Capital Projects Long-Term Prioritized Requirements
Passive County Parks: Plan, Funding
Comprehensive Countywide System/Stormwater Utility (Agreements with Municipalities)
2018 Priority Projects: Immediate Opportunities
Stormwater Management Program/Policy: Implementation
Okatie River Restoration: Funding
May River Action Plan
Rivers and Creeks Water Quality: Evaluation
Transfer of Development Rights
Buckingham Plantation Community Development Plan: Amendment

Memorandum

DATE: September 14, 2017

TO: Natural Resources Committee

FROM: Christopher S. Inglese, Assistant County Attorney

SUBJECT: Daufuskie Island Bailey Bill

Proposed Daufuskie Island Bailey Bill

10 Year Assessment Period 75% Initial investment

Issue: Should Daufuskie Island have a 20-year assessment period and a 20% initial investment standard in the proposed Daufuskie Island Bailey Bill when an existing County ordinance applicable within the City limits of Beaufort provides for a 10 year assessment period and a 75% initial investment?

Rationale: Consistency County wide is appropriate because: 1) there is no precedent for varying standards within a county, 2) because of administration of the Assessor's duties, 3) need to comply with constitutional principles of uniformity of tax assessment and equal protection, 4) avoid the predictable slippery slope of different communities expecting custom crafted standards, and 5) because of the potential fiscal impact.

1. **No precedent for varying standards of tax break**- Staff is not aware of any County that has substantive variations in the assessment period or initial investment amount among municipalities or geographic districts.

2. **Administrative needs**- Administration of the Assessor's duties is best served by a countywide standard. Varying standards will be a burden on staff, create opportunities for mistakes, and require manual entry outside of the automated systems created for efficiency and accuracy.

3. **Inconsistent with Constitutional Principals**- Article X Sec. 1- "The assessment of all property shall be equal and uniform" with regard to real and personal property. Subsequent state/local law (such as the Bailey Bill), must be in conformity with the Constitution. The Bailey Bill does not grant the County greater powers with regard to taxation than is granted under the Constitution, i.e. the power to customize tax assessments. Additionally, **S.C. Code of Laws 12-37-30** requires the uniform assessment of real property within a county.

    a. **Article I Sec. 23- Provisions of Constitution mandatory.** "The Provision of the Constitution shall be taken, deemed, and construed to be mandatory and prohibitory, and not merely directory, except where expressly made directory or permissory by its own terms."
    b. **Article I Sec.** 3- Includes the equal protection of the laws, which guarantees the equal application of the law to citizens of the State and its political subdivisions. In this case, the equal application of the Bailey Bill to all county taxpayers.

4. **Slippery slope**- Avoid the predictable pleas from different communities for a custom crafted ordinance.

5. **Fiscal Impact**- I believe the School District voiced its opposition to a 20-year special tax break because of the fiscal impact at the time the City of Beaufort ordinance was passed. While arguably negligible for the few properties eligible on Daufuskie Island, the longer the special tax break, the deeper the fiscal impact to the County and the School District.

The substantive arguments were vetted through the public hearing process at the time the City of Beaufort ordinance was passed and include:

75% v. 20%

The 75% Initial investment provides for a substantial investment that ensures the property will be visibly improved thereby benefiting neighboring properties and the community at large; a 20% investment may not be sufficient for any visible improvements to the property. Furthermore, a 20% investment may depreciate long before the expiration of a 20-year period thereby realizing no or nominal gain in assessed value over the course of 20 years.

10 Years v. 20 Years

A 10-year period for the special assessment provides for increased tax revenue to the County and School District after a reasonable time for recovering the initial investment. A 20-year period may allow for the property value and/or the condition of the property to deteriorate such that no increase in value due to improvements would be realized on the tax rolls.

From: Michael Bedenbaugh <oldhouse@palmettotrust.org>
Date: Monday, April 24, 2017 at 1:03 PM
To: "tvaux@bcgov.net" <tvaux@bcgov.net>, "gkubic@bcgov.net" <gkubic@bcgov.net>
Subject: Bailey Bill Implementation

Tabor and Gary

I appreciated the time y'all took to come visit Daufuskie and sit in on the council meeting. The connectivity between the island and the county is at a all time high and it says a lot about your dedication to open communication and availability.

Regarding the Bailey Bill, I have a link from the city of Columbia that shows how they recognize the implementation of the program.
Here it is: http://www.columbiasc.net/planning-preservation/historic-incentives

The top portion deals with the Bailey Bill and provides not only the ordinance but the application as well.

Implementing this act will go far in assuring that the historic fabric of Daufuskie will remain for future generations.

Thank you for helping us get this presented to Council. This is a priority for our mission in Beaufort County and Daufuskie and I will make it a priority to be as available to meet with you during work sessions and committee or council meetings to discuss this further.

Sincerely

Michael Bedenbaugh
Executive Director
Palmetto Trust for Historic Preservation
PO Box 506
117 Grace Street
Prosperity, SC 29127
803-924-9979

Help us save Daufuskie's Historic Gullah Homes http://www.gofundme.com/savinggullahhomes

EXCERPT FROM CITY OF COLUMBIA WEBSITE

Historic Incentives

Bailey Bill Historic Properties Tax Abatement Program

An incentive for owners of historic buildings, this City of Columbia program may enable you to keep your building's current assessed value at the same rate for 20 years. The property owner is required to make an investment of 20% of qualified expenses to qualify for the abatement. Richland County also offers its own Bailey Bill which generally mirrors the City's program. For more information, go to their website.

The Bailey Bill was passed by the state legislature in 1992 to give local governments the option of granting property tax abatement to encourage the rehabilitation of historic properties. Following amended state legislation in 2004, Columbia's City Council also adopted a local amended version of the bill in July of 2007.

All projects must be reviewed by the Design/Development Review Commission and your district's staff representative for eligibility prior to the start of work.

Bailey Bill Application

Bailey Bill Ordinance

Commercial Facade Improvement Loan Program

This City of Columbia multi-phase program has completed its round for the central business district along Main Street and is now focused on North Main Street. Funding through this program can be forgivable if certain criteria are met. Find out more through the Community Development Office.

For assistance with the Facade Improvement Loan Program please contact Gerry Lynn Hall at glhall@columbiasc.net or 803-545-3381. For the North Main Street Design District please contact John Fellows, Planning Administrator, at jsfellows@columbiasc.net or 803-545-3215.

South Carolina State Historic Preservation Office (SHPO)

Located in Columbia, the SHPO has a number of free educational resources available to historic property owners, and they also have certain tax credit programs available for qualifying renovations. They have all of the state's listings in the National Register of Historic Places, many of them with full-length nomination forms and photographs, which can be valuable tools for researching your community. The SHPO is housed in the same building as the S.C. Department of Archives and History, which maintains thousands of our state's historic documents.

Abandoned Buildings Act

In June 2013, the South Carolina State Legislature approved the Abandoned Buildings Act (ABA) in an effort to encourage the revitalization of abandoned buildings throughout the state. The ABA provides a tax credit to individuals who rehabilitate, renovate, and/or redevelop building sites.

The ABA offers two tax credit options:

1) A credit against income taxes, corporate, license fees or taxes on associations; or

2) A credit against real property taxes levied by local taxing entities.

The City of Columbia is only involved in the review and approval process when a taxpayer is seeking the credit against real property taxes. To qualify, a taxpayer must file a "Notice of Intent to Rehabilitate" with the City of Columbia Planning Division along with a completed application and signed affidavit. Planning staff will facilitate the review process. For more information about the Abandoned Buildings Act and how to apply for the tax credit, please contact Amy Moore at 803-545-3335 or aemoore@columbiasc.net.

Resources:

Frequently Asked Questions

Application

Abandoned Building Act Legislation

ORDINANCE 2017 / ___

AN ORDINANCE OF BEAUFORT COUNTY COUNCIL CREATING A SPECIAL TAX ASSESSMENT FOR REHABILITATED HISTORIC PROPERTIES IN THE GEOGRAPHICAL BOUNDARIES KNOWN AS DAUFUSKIE ISLAND

WHEREAS, Section 4-9-195 of the South Carolina Code of Laws, as amended ("S.C. Code"), provides that counties may by ordinance grant special property tax assessments to real property which qualifies as "rehabilitated historic property"; and

WHEREAS, the geographic area known as Daufuskie Island, in the County of Beaufort, South Carolina ("Daufuskie") contains a substantial amount of historic property, the preservation of which is beneficial for the economic development of the County and for its citizens; and

WHEREAS, Beaufort County Council (the "County Council") has determined that it is in the best interests of the County and its citizens to allow for a special property tax assessment available and as set forth in S.C. Code §4-9-195 to qualifying properties located within the geographic boundaries of Daufuskie; and

WHEREAS, the County Council finds that providing for this special property tax assessment will (1) encourage the restoration of historic properties, (2) promote community development and redevelopment, (3) encourage sound community planning, and (4) promote the general health, safety, and welfare of the community; and

WHEREAS, pursuant to S.C. Code §4-9-195, the County must specify the minimum investment threshold and the number of years in which the special assessment shall apply, and in the absence of a board of architectural review the County may name an appropriate reviewing authority to consider proposed rehabilitation plans and actual rehabilitation work.

NOW, THEREFORE, BE IT ORDAINED by Beaufort County Council that Chapter 66, Article III of the Beaufort County Code of Ordinances is hereby amended by inserting the following into Beaufort County Code of Ordinances Chapter 66, Division 4:

Division 4. Special Assessment Ratio for Rehabilitated Historic Properties

Section 66-155. Special tax assessment created –Daufuskie Island.

A special tax assessment is created for eligible rehabilitated historic properties located within the geographic boundaries of Daufuskie Island for 10 years equal to the appraised value of the property at the time of preliminary certification.

Section 66-156. Purpose.

It is the purpose of this division to:

(a) Encourage the restoration of historic properties;
(b) Promote community development and redevelopment;
(c) Encourage sound community planning; and
(d) Promote the general health, safety, and welfare of the community.

Section 66-157. Eligible properties.

(a) *Certification.* In order to be eligible for the special tax assessment, historic properties must receive preliminary and final certification.

(1) To receive preliminary certification a property must meet the following conditions:

a. The property has received historic designation from the Daufuskie Island Council and in accordance with the Daufuskie Island Plan or is listed on the Beaufort County Above Ground Historic Resources Survey completed in 1998.
b. The proposed rehabilitation work receives approval from the Beaufort County Historic Preservation Review Board (HPRB) under Sec. 5.10 and Sec. 7.2.120 of the Beaufort County Community Development Code (CDC).; and
c. Be a project that commences on or after the date of the adoption of this ordinance. Preliminary certification must be received prior to beginning work.

(2) To receive final certification, a property must have met the following conditions:

a. The property has received preliminary certification.
b. The minimum expenditures for rehabilitation were incurred and paid.
c. The completed rehabilitation receives approval from the Beaufort County Planning Director, or designee, as being consistent with the plans approved by the HPRB as part of preliminary certification.

(b) *Historic designation.* As used in this section, "Historic Designation" means:

(1) The structure is at least 50 years old and is located in the geographic area known as Daufuskie Island;
(2) The structure is listed on the National Register of Historic Places; or
(3) The structure is listed on the "1998 Beaufort County Above Ground Historic Sites Survey."

Section 66-158. Eligible rehabilitation.

(a) *Standards for rehabilitation work.* To be eligible for the special tax assessment, historic rehabilitations must be appropriate for the historic building and the geographic district. This is achieved through adherence to the standards set forth in the Community Development Code and, if required, approval of a Certificate of Appropriateness in accordance with Sec. 7.2.120 of the CDC.

(b) *Work to be reviewed.* The following work will be reviewed according to the standards set forth above:

(1) Repairs to the exterior of the designated building.
(2) Alterations to the exterior of the designated building.
(3) New construction on the property on which the building is located.
(4) Alterations to interior primary public spaces.
(5) Any remaining work where the expenditures for such work are being used to satisfy the minimum expenditures for rehabilitation.

(c) *Minimum expenditures for rehabilitation* means the owner rehabilitates the building, with expenditures for rehabilitation exceeding 75 percent of the fair market value of the building. Fair market value means the appraised value as certified by a real estate appraiser licensed by the State of South Carolina, the sales price as delineated in a bona fide contract of sale within 12 months of the time it is submitted, or the most recent appraised value published by the Beaufort County Tax Assessor.

(d) *Expenditures for rehabilitation* means the actual cost of rehabilitation relating to one or more of the following:

(1) Improvements located on or within the historic building as designated.
(2) Improvements outside of but directly attached to the historic building which are necessary to make the building fully useable (such as vertical circulation) but shall not include rentable/habitable floorspace attributable to new construction.
(3) Architectural and engineering services attributable to the design of the improvements.
(4) Costs necessary to maintain the historic character or integrity of the building.

(e) *Scope.* The special tax assessment may apply to the following:

(1) Structure(s) rehabilitated.
(2) Real property on which the building is located.

(f) *Time limits.* To be eligible for the special tax assessment, rehabilitation must be completed within two years of the preliminary certification date. If the project is not complete after two years, but the minimum expenditures for rehabilitation have been incurred, the property continues to receive the special assessment until the project is completed or until the end of the special assessment period, whichever shall first occur.

Section 66-159. Process.

(a) *Fee required.* A fee as set out in the County of Beaufort's Fee Schedule, as appropriate, shall be required for final certification for each application.

(b) *Plan required.* Owners of property seeking approval of rehabilitation work must submit an application for a Certificate of Appropriateness, as required under Sec. 7.2.120 of the CDC, with supporting documentation and application fee(s) prior to beginning work.

(c) *Preliminary certification.* Upon receipt of the completed application, the proposal shall be placed on the next available agenda of the Beaufort County Historic Preservation Review Board (HPRB). After the HPRB makes its' determination(s), the owner shall be notified in writing. Upon receipt of this determination the owner may:

(1) If the application is approved, apply for building permits to begin rehabilitation;
(2) If the application is not approved, may revise such application in accordance with comments provided by the HPRB.

(d) *Substantive changes.* Once preliminary certification is granted to an application, substantive changes must be approved by the HPRB. Unapproved substantive changes are conducted at the risk of the property owner and may disqualify the project from eligibility. Additional expenditures will not qualify the project for an extension on the special assessment.

(e) *Final certification.* Upon completion of the project, the project must receive final certification in order to be eligible for the special assessment. The Beaufort County Planning Director and Director of Building Codes, or designees, will inspect completed projects to determine if the work is consistent with the approval granted by the HPRB. Final certification will be granted when verification is made that expenditures have been made in accordance with Section 66-158(c) above. Upon receiving final certification, the property will be assessed for the remainder of the special assessment period on the fair market value of the property at the time the preliminary certification was made or the final certification was made, whichever occurred earlier.

(f) *Additional work.* For the remainder of the special assessment period after final certification, the property owner shall notify the Beaufort County Community Development Department of any additional work, other than ordinary maintenance. The HPRB will review the work at a regularly scheduled hearing and determine whether the overall project is consistent with the standards for rehabilitation. If the additional work is found to be inconsistent, the property owner may withdraw his request and cancel or revise the proposed additional work.

(g) *Decertification.* When the property has received final certification and has been assessed as rehabilitated historic property, it remains so certified and must be granted the special assessment until the property becomes disqualified by any one of the following:

(1) Written notice from the owner to the Beaufort County Assessor's Office requesting removal of the preferential assessment; or
(2) Rescission of the approval of rehabilitation by the HPRB because of alterations or renovation by the owner or the owner's estate, which causes the property to no longer possess the qualities and features which made it eligible for final certification.

Notification of any change affecting eligibility must be given immediately to the Beaufort County Assessor, Auditor, and Treasurer.

(h) *Notification.* The Beaufort County Community Development Department shall, upon final certification of a property, notify the Beaufort County Assessor, Auditor and Treasurer that such property has been duly certified and is eligible for the special tax assessment.

(i) *Date effective.* If an application for preliminary or final certification is filed by May 1 or the preliminary or final certification is approved by August 1, the special assessment authorized herein is effective for that year. Otherwise, it is effective beginning with the following year.

The special assessment only begins in the current or future tax years as provided for in this section. In no instance may the special assessment be applied retroactively.

(j) *Application.* Once a property has received final certification, the owner of the property shall make application to the Beaufort County Auditor's Office for the special assessment provided for herein.

SECTIONS 66-160. Reserved.

This ordinance shall become effective immediately upon adoption.

DONE, this ____ of __________________, 2017.

COUNTY COUNCIL OF BEAUFORT COUNTY

By: ____________________________________
D. Paul Sommerville, Chairman

APPROVED AS TO FORM:

____
Thomas J. Keaveny, II, Esquire
Beaufort County Attorney

ATTEST:

____
Ashley M. Bennett, Clerk to Council

First Reading: May 22, 2017
Second Reading:
Public Hearing:
Third and Final Reading:

<u>**August 23, 2016**</u>
Daufuskie Island Council Resolution

"The Bailey Bill on Daufuskie Island"

Background
South Carolina state legislation enacted in 1992 and amended in 2004, known popularly as "The Bailey Bill" is a local real estate tax incentive for rehabilitation of historic property. It freezes the taxable assessed value of a property for up to 20 years following a minimum investment threshold, review and approval of the project, and successful completion of the project within two years.

The Daufuskie Island Council, in establishing a committee to study the effects of the Bailey Bill on Daufuskie Island Historic District, has met with members of the Beaufort County Council, Beaufort County Staff and citizens of Daufuskie in order to determine the suitability of the application of the Bailey Bill on historic property located on Daufuskie Island.

To this end, the Daufuskie Island Council has adopted the following resolution which is being forwarded to the Beaufort County Council:

Whereas, Daufuskie Island is a special planning district located in Beaufort County; and

Whereas, Daufuskie Island has a Historic District that contains many buildings listed on the National Register as contributing to the historic district, and

Whereas, these historic buildings reflect the unique history of a SC Sea Island inhabited by Gullah and white landowners who existed on the island prior to the encroachment of modern late 20^{th} century development, and

Whereas, due to the uniqueness of the quantity and quality of these historic buildings, a thriving tourist industry has developed with visitors wanted to see and experience these historic places first hand, and

Whereas, because of the isolation of the island and difficulty in maintaining the privately owned properties, many of the historic structures listed on the National Register have been degraded and deteriorated to the point of where they might face eminent demolition, by either action or neglect, and

Whereas, many of the owners are not incentivized to invest in these historic structures due to the increase of Property taxes and the additional financial burden that could entail on their limited finance's, and

Whereas, the loss of these historic places could have a negative impact on tourism revenue for the islands property owners.

THEREFORE, BE IT
RESOLVED, that the Daufuskie Island Council strongly recommends that the Beaufort County Council enact the Bailey Bill for the Island of Daufuskie; and be it further

RESOLVED, that the Daufuskie Island Council urges the Beaufort County Council to give approval for an abatement of property tax for buildings listed on the National Register to be fixed at pre rehabilitation level for the full 20-year period and for the amount of investment equal to 20% of the value of the property.

ADOPTED BY UNANIMOUS VOTE OF THE DAUFUSKIE ISLAND COUNCIL ON FRIDAY, August 23, 2016.

Charlie Small, Chairman
Chuck Hunter, Vice-Chairman
David Hutton, Vice-Chairman
Janet Adams
Tine Fine
Steve Hill
Len Pojednic
John Schartner
Deborah Smith

MEMORANDUM

To: Natural Resources Committee of Beaufort County Council

From: Anthony Criscitiello, Beaufort County Community Development Director

Subject: Amendment to the Beaufort County Community Development Code - Aquaponics

Date: September 13, 2017

PLANNING COMMISSION RECOMMENDATION from the excerpt of its September 7, 2017, draft minutes:

Mr. Criscitiello briefed the Commission and noted his research regarding aquaponics. There has been a decline in farming and this concept may reverse that trend in Beaufort County. He contemplated the reasoning adding the use to one district that the applicant requested versus all other districts where agriculture was allowed. Staff concurred with the applicant and felt it was beneficial to broaden the requested text amendment to all districts that allow agriculture uses. Staff has included the special use approval and other areas of changes. The special use was recommended so that the applicants would go before the Zoning Board of Appeals to weigh their individual applications. He noted that excavation of the ground was prohibited to prevent any mining applications under this proposed amendment.

Applicant's Comment: Mr. Ed Krebs, the applicant, noted that when he spoke to the Planning staff, they had no idea what was aquaponics. He gave kudos to the deeply researched staff report supporting his request. He noted his property was in Pritchardville in T3-Edge zoning that was allowed a greenhouse garden, but disallowed aquaculture (fish growing). He noted his handout to the Commissioners. He noted the traditional ways of raising fish was in outdoor ponds. He would be raising koi, not tilapia, in his aquaponics system. He mentioned that his wife was a biologist and a naturalist, so would not support outdoor fish ponds. His system would be an all-natural, completely organic system, where he would feed the fish--no fertilizer, no chemicals, no pesticides, and no herbicides. The system will produce 120,000 heads of lettuce a year and 100 koi each month that will grow in the system for a year. They will have a store where they will sell their lettuce and koi, and have a small classroom for people to view and learn about the aquaponics system—especially children and college level students. The investment is slightly under $400,000 and will employ three people. He was looking for something that was lightweight.

Discussion by Commission included determining the regulatory authority for aquaponics systems *(Mr. Krebs stated that his research indicated Clemson Extension had the authority.)*, the types of fish allowed in aquaponics *(Mr. Krebs noted that catfish, koi, brim, tilapia, etc.; but processing fish would involve another authority.)*, acknowledging aquaponics systems elsewhere *(Mr. Krebs noted Hawaii and Midwest, with Hawaii being outdoors because the weather is mild. As a commercial entity, being outdoors would not work because there would be a 5-month season. Technically outdoors would work, but practically you would not cover your investment in such a short season. The greenhouse system would require 4 months before the first lettuce* *can be harvested.)*, clarifying the site requirements involving greenhouses rather than outdoors *(Mr. Krebs noted that 10-20 acres of farmland equates to 80,000 square feet of greenhouse for aquaponics.)*, agreeing with the staff for a controlled environment on this innovative process, and concern with private fish pond verbiage confusing for one who wants decorative fish pond *(Mr. Criscitiello noted that this concern would be related to the next text amendment.)*.

Public Comment: None were received

Motion: Mr. Randolph Stewart made a motion, and Ms. Caroline Fermin seconded the motion, **to recommend to County Council approval of Text Amendment to the Community Development Code (CDC): Section 3.1.70 Land Use Definitions, Agriculture, to add the Aquaponics use to agriculture and crop harvesting land use type, as a special use and with the other recommendation by staff.** Further discussion included clarification of the motion. The motion **carried (FOR: Chmelik, Fermin, Hincher, Pappas, Semmler, and Stewart; ABSENT: Mitchell; VACANCIES: St. Helena Island and Southern Beaufort County (Walsnovich) and Fireall).**

STAFF REPORT:

A. BACKGROUND:

Case No.	ZTA 2017-12
Applicant:	E. D. Krebs III
Proposed Text Change:	Amendment to Add "Aquaponics" in the Section 3.1.70 Agriculture and Crop Harvesting Land Use Type

B. SUMMARY OF REQUEST:

The proposed amendment would change the Land Use definitions in Table of 3.1.70, Section 1, Agriculture and Crop Harvesting, to add "Aquaponics" in the definition for Agriculture and Crop Harvesting land use type. The term "Aquaponics" refers to a farming technique that is organic in nature using an ultra-low water use process involving fish in tanks in conjunction with floating rafts with vegetables, usually leaf lettuce.

The fish are fed organic food and water from the fish tanks; and then, the by-product is circulated through a bed of expanded clay particles where a beneficial bacterium removes the impurities. The water continues from there into float beds where the roots of the plants are immersed under the foam floats that hold up the leafy parts of the plants. The plants use the nutrients in the water to grow to maturity and the water is then pumped back into the fish tanks where the process continues its cycle all over again.

The entire process is housed in an enclosed greenhouse to protect from outside contamination. Typically there is no need for fertilizers, pesticides, or herbicides. Other than the initial load of water at start-up, no water changes are required. Excavation of the land area of the parcel is not permitted with this technique of farming.

C. ANALYSIS:

Sec. 7.7.30(C). Code Text Amendment Review Standards. The advisability of amending the text of this Development Code is a matter committed to the legislative discretion of the County Council and is not controlled by any one factor. In determining whether to adopt or deny the proposed text amendment, the County Council shall weigh the relevance of and consider whether, and the extent to which, the proposed amendment:

1. **Is consistent with the goals, objectives, and policies of the Comprehensive Plan;**

   The proposed amendment is consistent with preserving and enhancing agriculture as a way of life in Beaufort County and is vital to maintaining the county's economic and demographic diversity by providing economic opportunities to rural residents and landowners, reducing the pressures of sprawl, providing a source of local fresh produce, and retaining the traditions and characteristics that make this region unique (Culture Resource Element, page 6-11). Also, as a cottage industry, farmers should be encouraged to produce food items not only for farmers' markets and grocery outlets, but also for local and regional restaurants as well as schools, hospitals, or other institutional cafeterias. (Economic Development Element, page 7-21).

   Finally, the way the food is produced and transported has an impact on the environment and energy consumption. The term "food miles" refers to the distance that food travels from the farm on which it is produced to the kitchen in which it is prepared. Food travels between 1,500 to 2,500 miles every time that it is delivered to the consumer. (Energy Element, page 9-16)

2. **Is not in conflict with any provision of this Development Code or the Code of Ordinances;**

   The proposed change does not conflict with other provisions of the Development Code or Code of Ordinances.

3. **Is required by changed conditions;**

   Not Applicable.

4. **Addresses a demonstrated community need;**

   The Cultural Resources Element of the Comprehensive Plan notes a continuous decline in the number of farms and the land in acreage dedicated to farming activities. The means and methods to improve farming activities in Beaufort County should be pursued in order to arrest the overall decline in farming as an important way of life. Also, an innovation in farming like aquaponics is an intriguing possibility that should not be hindered by regulatory barriers to farming.

5. **Is consistent with the purpose and intent of the zones in this Development Code, or would improve compatibility among uses and ensure efficient development within the County;**

   This amendment is consistent and would promote agriculture and crop harvesting in zoning districts that allow agriculture and crop harvesting as a permitted use. Those districts can be found in the Community Development Code in Table 3.1.60 Consolidated Use Table and include T1N, T2R, T2RL, T2RN, T2RNO, T3RC, and T3E.

6. **Would result in a logical and orderly development pattern; and**

   See responses to Items 4 and 5 above.

7. **Would not result in adverse impacts on the natural environment, including but not limited to water, air, noise, stormwater management, wildlife, vegetation, wetlands, and the natural functioning of the environment.**

   Aquaponics is essentially the combination of aquaculture and hydroponics. Both aquaculture and hydroponics have limitations—hydroponics requires expensive nutrients to feed the plants, and also requires periodic flushing of the systems which can lead to waste disposal issues. Re-circulating aquaculture water needs to have excess nutrients removed from the system; normally this means that a percentage of the water is removed, generally on a daily basis.

Aquaponics is a bio-integrated system that links recirculating aquaculture with hydroponic vegetable, flower, and/or herb production. Recent advances by researchers and growers have turned aquaponics into sustainable food production model.

D. STAFF RECOMMENDATION:

After review of the standards set forth in Section 7.7.30(C) of the Community Development Code, staff **recommends Special Use Approval with the following conditions:** (new language underscored):

1. Aquaponics may be permitted in all districts that allow agriculture and crop harvesting as a special use with compliance with accessory use standards to be reviewed and approved by the Staff Review Team and the Zoning Board of Appeals.
2. The following language is proposed for Table 4.1.340 Aquaponics

    A. An operational plan shall be submitted that indicates that this use will result in no adverse impacts on neighboring properties including noise and odors.

    B. The principle product of aquaponics shall be vegetables with fish available from time to time as a bi-product.

    C. All standards that apply to the zoning districts which allow Agriculture and Crop Harvesting shall be followed, and aquaponics may be an accessory use on the site.

    D. The entire aquaponics process shall take place inside an enclosed greenhouse to protect from outside contaminants, and the need for pesticides or herbicides is to be avoided.

    E. No excavation of the ground to create the potential of sand mining shall be allowed in the pursuit of an aquaponics zoning permit.

E. ATTACHMENTS:

- Proposed Ordinance Amendments
- Application

Table 3.1.60. Consolidated Use Table

Land Use Type	T1 N	T2R	T2 RL	T2 RN	T2 RNO	T2 RC	T3E	T3 HN	T3 N	T3 NO	T4 HC	T4 VC	T4 HCO	T4 NC	C3	C4	C5	SI
AGRICULTURE																		
1. Agriculture & Crop Harvesting	P	P	P	P	P	P	P	--	--	--	--	--	--	--	P	--	--	--
2. Aquaponics	S	S	S	S	S	S	S								S			
3. Agricultural Support Services	--	P	P	P	P	P	--	--	--	--	P	P	P	--	TCP	P	P	P
4. Animal Production	--	C	--	C	C	C	--	--	--	--	--	--	--	--	--	--	--	--
5. Animal Production: Factory Farming	--	S	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6. Seasonal Farmworker Housing	--	C	C	C	C	C	C	--	--	--	--	--	--	--	C	--	--	--
7. Forestry	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
8. Commercial Stables	--	C	C	C	C	C	--	--	--	--	--	--	--	--	C	--	--	--

Table 3.1.70 Land Use Definitions

AGRICULTURE

This category is intended to encompass land uses connected with a business or activity involving farming, animal production, forestry, and other businesses serving primarily agricultural needs.

Land Use Type	Definition
1. Agriculture and Crop Harvesting	A nursery, orchard, or farm, greater than 10,000 SF, primarily engaged in the growth and harvesting of fruits, nuts, vegetables, plants, or sod. The premises may include agricultural accessory structures, plant nurseries, and secondary retail or wholesale sales.
2. Aquaponics	The symbiotic use of plants and fish in single environment where the fish thrive off of the plant waste and the plants absorb the fish waste as fertilizer. Both the fish and the plants are harvested.
3. Agricultural Support Services	Nursery, orchard, forestry, or farm supply and support services including, but not limited to: equipment dealers, support uses for agricultural, harvesting, and/or animal production, seasonal packing sheds, etc.
4. Animal Production	The raising, breeding, feeding, and/or keeping of animals for the principal purpose of commercially producing products for human use or consumption, including, but not limited to: cattle, pigs, sheep, goats, fish (aquaculture), bees, rabbits, and poultry. This does not include "Factory Farming" operations.
5. Animal Production: Factory Farming	The raising, breeding, feeding, and/or keeping of livestock (typically cows, pigs, turkeys, or chickens) in confinement at high stocking density for the purpose of commercially producing meat, milk, or eggs for human consumption.
6. Seasonal Farmworker Housing	Housing located on farmland for temporary occupancy during seasonal farming activity.
7. Forestry	Perpetual management, harvesting, replanting, and enhancement of forest resources for ultimate sale or use of wood products, subject to S.C. Forestry Commission BMPs.
8. Commercial Stables	Stabling, training, feeding of horses, mules, donkeys, or ponies, or the provision of riding facilities for use other than by the resident of the property, including riding academies. Also includes any structure or place where such animals are kept for riding, driving, or stabling for compensation or incidental to the operation of any club, association, ranch or similar purpose.

4.1.340 Aquaponics

Aquaponics shall comply with the following:

A. An operational plan shall be submitted that indicates that this use will result in no adverse impacts on neighboring properties including noise and odors.

B. The principle product of aquaponics shall be vegetables with fish available from time to time as a bi-product.

C. All standards that apply to the zoning districts which allow Agriculture and Crop Harvesting shall be followed, and aquaponics may be an accessory use on the site.

D. The entire aquaponics process shall take place inside an enclosed greenhouse to protect from outside contaminants, and the need for pesticides or herbicides is to be avoided.

E. No excavation of the ground to create the potential of sand mining shall be allowed in the pursuit of an aquaponics zoning permit.

E. T1 Allowed Uses		
Land Use Type[1]	**Specific Use Regulations**	**T1**
Agricultural		
Agriculture & Crop Harvesting		P
Aquaponics	4.1.340	S
Forestry		P
Residential		
Dwelling: Single Family Detached Unit		P
Dwelling: Group Home		P
Home Office	4.2.90	C
Recreation, Education, Safety , Public Assembly		
Park, Playground, Outdoor Recreation Areas	2.8	P
Recreation Facility: Campground	4.1.190	S
Ecotourism	4.1.330	S

Key	
P	Permitted Use
C	Conditional Use
S	Special Use Permit Required
---	Use Not Allowed
End Notes	

[1] A definition of each listed use type is in Table 3.1.70 Land Use Definitions.

H. T2R Allowed Uses

Land Use Type[1]	Specific Use Regulations	T2R	T2RL
Agricultural			
Agriculture & Crop Harvesting		P	P
Aquaponics	4.1.430	S	S
Agricultural Support Services		P	P
Animal Production	4.1.30	C	---
Animal Production: Factory Farming	4.1.30	S	---
Seasonal Farmworker Housing	4.1.90	C	C
Forestry		P	P
Commercial Stables	4.1.50	C	C
Residential			
Dwelling: Single Family Detached Unit		P	P
Dwelling: Accessory Unit	4.2.30	C	C
Dwelling: Family Compound	2.7.40	C	C
Dwelling: Group Home		P	P
Home Office	4.2.90	C	C
Home Business	4.2.80	C	---
Cottage Industry	4.2.40	C	---
Retail & Restaurants			
General Retail 3,500 SF or less	4.1.120	C	---
Gas Station/Fuel Sales	4.1.100	S	---
Offices & Services			
Animal Services: Kennel	4.1.40	C	---
Day Care: Family Home (up to 8 clients)		P	P
Lodging: Bed & Breakfast (5 rooms or less)	7.2.130	S	S
Lodging: Inn (up to 24 rooms)	7.2.130	S	---

Land Use Type[1]	Specific Use Regulations	T2R	T2RL
Recreation, Education, Safety, Public Assembly			
Community Public Safety Facility		P	P
Institutional Care Facility	7.2.130	S	---
Detention Facility	7.2.130	S	---
Meeting Facility/Place of Worship (less than 15,000 SF)	4.1.150	C	---
Meeting Facility/Place of Worship (15,000 SF or greater)	4.1.150	S	---
Park, Playground, Outdoor Recreation Areas	2.8	P	P
Recreation Facility: Commercial Outdoor	4.1.200	S	---
Recreation Facility: Golf Course		P	---
Recreation Facility: Campground	4.1.190	C	---
Ecotourism	4.1.330	C	---
Infrastructure, Transportation, Communications			
Airport, Aviation Services	7.2.130	S	---
Infrastructure and Utilities: Regional (Major) Utility	4.1.210	C	C
Waste Management: Community Waste Collection & Recycling	4.1.290	C	---
Waste Management: Regional Waste Transfer & Recycling	4.1.300	S	---
Waste Management: Regional Waste Disposal & Resource Recovery	4.1.310	S	---
Wireless Communications Facility	4.1.320	S	S
Industrial			
Mining & Resource Extraction	4.1.160	S	S

Key	
P	Permitted Use
C	Conditional Use
S	Special Use Permit Required
---	Use Not Allowed

End Notes

[1] A definition of each listed use type is in Table 3.1.70 Land Use Definitions.

H. T2RN Allowed Uses

Land Use Type[1]	Specific Use Regulations	T2RN	T2RNO
Agricultural			
Agriculture & Crop Harvesting		P	P
Aquaponics	4.1.430	S	S
Agricultural Support Services		P	P
Animal Production	4.1.30	C	C
Seasonal Farmworker Housing	4.1.90	C	C
Forestry		P	P
Commercial Stables	4.1.50	C	C
Residential			
Dwelling: Single Family Detached Unit		P	P
Dwelling: Accessory Unit	4.2.30	C	C
Dwelling: Family Compound	2.7.40	C	C
Dwelling: Group Home		P	P
Home Office	4.2.90	C	C
Home Business	4.2.80	C	C
Cottage Industry	4.2.40	C	C
Live/Work		---	P
Retail & Restaurants			
General Retail 3,500 SF or less		---	P
Restaurant, Café, Coffee Shop		---	P

Land Use Type[1]	Specific Use Regulations	T2RN	T2RNO
Offices & Services			
General Offices & Services 3,500 SF or less		---	P
Day Care: Family Home (Up to 8 clients)		P	P
Day Care: Commercial Center (9 or more clients)	4.1.60	---	C
Lodging: Bed & Breakfast (5 rooms or less)		---	P
Medical Offices: Clinics/ Offices		---	P
Recreation, Education, Safety, Public Assembly			
Community Public Safety Facility		P	P
Meeting Facility/Place of Worship (Less than 15,000 SF)	4.1.150	C	C
Park, Playground, Outdoor Recreation Areas		P	P
Ecotourism	4.1.330	C	C
Infrastructure, Transportation, Communications			
Infrastructure and Utilities: Regional (Major) Utility	4.1.210	C	C
Wireless Communication Facility	4.1.320	S	S

Key	
P	Permitted Use
C	Conditional Use
S	Special Use Permit Required
---	Use Not Allowed

End Notes

[1] A definition of each listed use type is in Table 3.1.70 Land Use Definitions.

G. T2RC Allowed Uses

Land Use Type[1]	Specific Use Regulations	T2RC
Agricultural		
Agriculture & Crop Harvesting		P
Aquaponics	4.1.430	S
Agricultural Support Services		P
Animal Production	4.1.30	C
Seasonal Farmworker Housing	4.1.90	C
Forestry		P
Commercial Stables	4.1.50	C
Residential		
Dwelling: Single Family Detached Unit		P
Dwelling: Accessory Unit	4.2.30	C
Dwelling: Family Compound	2.7.40	C
Dwelling: Group Home		P
Community Residence (dorms, Convents, assisted living, temporary shelters)		P
Home Office	4.2.90	C
Home Business	4.2.80	C
Cottage Industry	4.2.40	C
Retail & Restaurants		
General Retail 25,000 SF or less		P
Bar, Tavern, Nightclub		P
Gas Station/Fuel Sales	4.1.100	C
Open Air Retail		P
Restaurant, Café, Coffee Shop		P
Vehicle Sales and Rental: Light	4.1.260	C
Offices & Services		
General Offices & Services <10,000 SF		P
General Offices & Services: with Drive-Through Facilities	4.1.70	C
Animal Services: Clinic/Hospital		P
Animal Services: Kennel	4.1.40	C
Day Care: Family Home (up to 8 Clients)		P
Day Care: Commercial Center (9 or more clients)	4.1.60	C
Lodging: Bed & Breakfast (5 rooms or less)		P
Lodging: Inn (up to 24 rooms)		P
Medical Service: Clinics/Offices		P
Vehicle Services: Minor Maintenance And Repair	4.1.270	C
Vehicle Services: Major Maintenance And Repair	4.1.270	C

Land Use Type[1]	Specific Use Regulations	T2RC
Recreation, Education, Safety, Public Assembly		
Community Oriented Cultural Facility (less than 15,000 SF)		P
Community Oriented Cultural Facility (greater than 15,000 SF)	7.2.130	S
Community Public Safety Facility		P
Institutional Care Facility	7.2.130	S
Meeting Facility/Place of Worship (less than 15,000 SF)	4.1.150	C
Meeting Facility/Place of Worship (15,000 SF or greater)	4.1.150	C
Park, Playground, Outdoor Recreation Areas		P
Recreation Facility: Community-Based		P
Ecotourism	4.1.330	C
School: Public or Private	7.2.130	S
School: Specialized Training/Studio	7.2.130	S
School: College or University	7.2.130	S
Infrastructure, Transportation, Communications		
Infrastructure and Utilities: Regional (Major) Utility	4.1.210	C
Parking Facility, Public or Commercial		P
Transportation, Terminal	7.2.130	S
Waste Management: Community Waste Collection & Recycling	4.1.290	C
Wireless Communications Facility	4.1.320	S
Industrial		
Manufacturing, Processing, and Packaging - Light (less than 15,000 SF)	4.1.140	C
Outdoor Maintenance / Storage Yard	4.1.180	C
Warehousing	4.1.280	C
Wholesaling and Distribution	4.1.280	C

Key	
P	Permitted Use
C	Conditional Use
S	Special Use Permit Required
---	Use Not Allowed

End Notes

[1] A definition of each listed use type is in Table 3.1.70 Land Use Definitions.

G. T3 E Allowed Uses

Land Use Type[1]	Specific Use Regulations	T3E
Agricultural		
Agriculture & Crop Harvesting		P
Aquaponics	4.1.430	S
Seasonal Farmworker Housing	4.1.90	C
Forestry		P
Residential		
Dwelling: Single Family Detached Unit		P
Dwelling: Accessory Unit	4.2.30	C
Dwelling: Family Compound	2.7.40	C
Dwelling: Group Home		P
Community Residence (dorms, convents, assisted living, temporary shelters)		P
Home Office	4.2.90	C
Home Business	4.2.80	C

Land Use Type[1]	Specific Use Regulations	T3E
Offices & Services		
Day Care: Family Home (up to 8 clients)		P
Lodging: Bed & Breakfast (5 rooms or less)		P
Recreation, Education, Safety, Public Assembly		
Meeting Facility/Place of Worship (Less than 15,000SF)	4.1.150	C
Park, Playground, Outdoor Recreation Areas		P
Infrastructure, Transportation, Communications		
Infrastructure and Utilities: Regional (Major) Utility	4.1.210	S

Key	
P	Permitted Use
C	Conditional Use
S	Special Use Permit Required
---	Use Not Allowed

End Notes

[1] A definition of each listed use type is in Table 3.1.70 Land Use Definitions.

BEAUFORT COUNTY, SOUTH CAROLINA
PROPOSED COMMUNITY DEVELOPMENT CODE (CDC)
ZONING MAP OR TEXT AMENDMENT / PUD MASTER PLAN CHANGE APPLICATION

TO: Beaufort County Council

The undersigned hereby respectfully requests that the Beaufort County Zoning/Development Standards Ordinance (ZDSO) be amended as described below:

RECEIVED AUG 1 0 2017 PLANNING DIVISION

1. This is a request for a change in the (check as appropriate): ( ) PUD Master Plan Change
( ) Zoning Map Designation/Rezoning (✓) Community Development Code Text

2. Give exact information to locate the property for which you propose a change:
Tax District Number:__________, Tax Map Number:______, Parcel Number(s):__________
Size of subject property:____________________ Square Feet / Acres (circle one)
Location:____________________

3. How is this property presently zoned? (Check as appropriate)

( ) T4NC Neighborhood Center	( ) T2RC Rural Center	( ) C3 Neighborhood Mixed Use
( ) T4HC Hamlet Center	( ) T2RN Rural Neighborhood	( ) C4 Community Center Mixed Use
( ) T4HCO Hamlet Center	( ) T2RNO Rural Neighborhood Open	( ) C5 Regional Center Mixed Use
( ) T4VC Village Center	( ) T2R Rural	( ) S1 Industrial
( ) T3N Neighborhood	( ) T1 Natural Preserve	( ) Planned Unit Development/PUD
( ) T3HN Hamlet Neighborhood	( ) Community Preservation	(name)________
(✓) T3E Edge	(specify)________	

4. What new zoning do you propose for this property?____________________
(Under Item 9 explain the reason(s) for your rezoning request.)

5. Do you own all of the property proposed for this zoning change? (✓) Yes ( ) No
Only property owners or their authorized representative/agent can sign this application. If there are multiple owners, each property owner must sign an individual application and all applications must be submitted simultaneously. If a business entity is the owner, the authorized representative/agent of the business must attach: 1- a copy of the power of attorney that gives him the authority to sign for the business, and 2- a copy of the articles of incorporation that lists the names of all the owners of the business.

6. If this request involves a proposed change in the Community Development Code text, the section(s) affected are: Sec. 3.1.70
(Under Item 9 explain the proposed text change and reasons for the change.)

7. Is this property subject to an Overlay District? Check those which may apply:

( ) MCAS-AO Airport Overlay District/MCAS	( ) MD Military Overlay District
( ) BC-AO Airport Overlay District/Beaufort County	( ) RQ River Quality Overlay District
( ) CPO Cultural Protection	( ) TDR Transfer of Development Rights
( ) CFV Commercial Fishing Village	

8. The following sections of the Community Development Code (CDC) (see attached sheets) should be addressed by the applicant and attached to this application form:
   a. Division 7.3.20 and 7.3.30, Comprehensive Plan Amendments and Text Amendments.
   b. Division 7.3.40, Zoning map amendments (rezoning).
   c. Division 1.6.60, Planned Unit Developments (PUDs) Approved Prior to Dec. 8, 2014
   d. Division 6.3, Traffic Impact Analysis (for PUDs)

9. Explanation (continue on separate sheet if needed): — SHEET ATTACHED —

It is understood by the undersigned that while this application will be carefully reviewed and considered, the burden of proof for the proposed amendment rests with the owner.

[signature] 8/9/17
Signature of Owner (see Item 5 on page 1 of 2) Date

Printed Name: E. D. KREBS III Telephone Number: 843-384-1096

Prop. Address: 179 GIBBET ROAD - BLUFFTON, SC 29910

Email: EDK @ SOLARFARMSOFAMERICA.COM

Agent (Name/Address/Phone/email):

UPON RECEIPT OF APPLICATIONS, THE STAFF HAS THREE (3) WORK DAYS TO REVIEW ALL APPLICATIONS FOR COMPLETENESS. THE COMPLETED APPLICATIONS WILL BE REVIEWED FIRST BY THE BEAUFORT COUNTY PLANNING COMMISSION SUBCOMMITTEE RESPONSIBLE FOR THE AREA WHERE YOUR PROPERTY IS LOCATED. MEETING SCHEDULES ARE LISTED ON THE APPLICATION PROCESS (ATTACHED). COMPLETE APPLICATIONS MUST BE **SUBMITTED BY *NOON* THREE WORKING DAYS AND FOUR (4) WEEKS PRIOR FOR PLANNED UNIT DEVELOPMENTS (PUDs) OR THREE (3) WEEKS PRIOR FOR NON-PUD APPLICATIONS** TO THE APPLICABLE PLANNING COMMISSION MEETING DATE.

PLANNED UNIT DEVELOPMENT (PUD) APPLICANTS ARE REQUIRED TO SUBMIT FIFTEEN (15) COPIES TO THE PLANNING DEPARTMENT. CONSULT THE APPLICABLE STAFF PLANNER FOR DETAILS.

FOR MAP AMENDMENT REQUESTS, THE PLANNING OFFICE WILL POST A NOTICE ON THE AFFECTED PROPERTY AS OUTLINED IN DIV. 7.4.50 OF THE COMMUNITY DEVELOPMENT CODE.

CONTACT THE PLANNING DEPARTMENT AT (843) 255-2140 FOR EXACT APPLICATION FEES.

FOR PLANNING DEPARTMENT USE ONLY:

Date Application Received:
(place received stamp below)

Date Posting Notice Issued:

Application Fee Amount Received:

Receipt No. for Application Fee:

Edward D. Krebs

30 Lake View Court
Bluffton, SC 29910
843-384-1096

The following refers to Zone T3 Edge

We are requesting a text change to one section of the land use definition (3.1.70, section 1 - Agriculture and Crop Harvesting).

This section (section 1) does not include a new farming method referred to as "Aquaponics". Aquaponics is an organic, ultra-low water use farming system that uses fish in tanks in conjunction with floating rafts with vegetables, usually leaf lettuce. The fish are fed organic food and the water from the fish tanks is circulated through a bed of expanded clay particles where beneficial bacteria removes impurities. The water continues from there into the float beds where the roots of the plants are immersed under foam floats that hold up the leafy parts. The plants use the nutrients in the water to grow and the water is then pumped back into the fish tanks where the process continues its cycle over again.

The entire process takes place inside an enclosed greenhouse to protect from outside contaminants, therefore there is no need for fertilizer, pesticides or herbicides. Other than the initial load of water at start-up, no water changes are required. Only 2% of the water is lost and most of that is taken up by the plants.

Section 3 of 3.1.70 Animal Production, states that raising fish via aquaculture is not allowed in Zone T3 Edge, but does not mention raising fish as part of the aquaponic production of vegetables.

"Aquaculture" is generally thought of as fish farms, employing large ponds in the ground with dikes between and water wheels to circulate and aerate. These ponds require draining to harvest and need to dry out to kill off pathogens, produced by too many fish in one place, between stocking. This process uses large quantities of water and land. Aquaculture's product is fish, Aquaponics product is vegetables with small amounts of fish available from time to time.

Therefore, we ask that you insert the word "Aquaponics" in section 1 in order to allow this type of modern, organic farming in Zone T3Edge.

Sincerely

Ed Krebs

MEMORANDUM

To: Natural Resources Committee of Beaufort County Council

From: Anthony J. Criscitiello, Community Development Director

Subject: Amendment to Article 4, Section 4.2.20 of the Community Development Code to Allow Private Fish Ponds in the T3 Neighborhood District

Date: September 13, 2017

PLANNING COMMISSION RECOMMENDATION from the excerpt of its September 7, 2017, draft minutes:

Mr. Merchant briefed the Commission with the current requirements. He noted the proposed requirements included a 1-acre private fish pond on a minimum 3-acre lot, with slope and noise standards. The proposed text amendment is restricted to a 1-acre pond to prevent mining activity where dirt is removed from the property for resale. He gave the rationale for the staff including all the T3 Zoning Districts in this text amendment. Staff recommended approval with the additional requirements including all the T3 zoning districts, a truck routing plan, and returning the road to the standard it was prior to hauling the dirt off the property. He noted that this is not aquaculture which is restricted to the T2 Zoning Districts.

Discussion by Commission included clarifying fish ponds for personal use, concern that this would exclude those in smaller lots from building a small personal fish pond for aesthetics, concern that a small water feature would be denied for smaller lots, clarifying the difference between a fish pond and a stormwater pond, clarifying the staff's goal to limit land mining, concern with the cleanliness of 1-acre pond—especially algae bloom, safety concern for trucks on the roads during school hours, and adding a requirement to prevent algae bloom in such ponds.

Applicant's Comment: Mr. David Karlyk of Carolina Engineering, is a representative of the applicant (Mr. Humphries) and the owner of the property—Mr. Trey Smith, noted that Mr. Smith owns and lives on the property (behind Bi-Lo in Shell Point) with his family. He is trying to encourage his 4 sons to be involved with nature. His sons currently fish out of the drainage pond behind the Medical Center. Mr. Smith has 8 acres and he realizes the pond would attract wildlife—birds, fish, etc.; however, his children will not have to leave his property to fish. His property is surrounded by a County park and undeveloped property currently owned by the bank, so he is not impacting any of his neighbors. Mr. Karlyk noted that wet detention ponds are promoted by the County drainage standards to treat fecal coliform. He also noted he lives in the Telfair subdivision where there are several drainage ponds that have existed for 15-18 years, that are without algae blooms. Mr. Karlyk sees this as a benefit to Mr. Smith's property, not a detriment.

Commission discussion included clarifying whether the applicant could ask for a special use *(Mr. Merchant said the Code specifically does not allow such application since the applicant's property is in the T3-Neighborhood zone.)*, concern that such hauling of dirt should be regulated, clarifying that a 12-foot deep 1-acre pond did not involve a lot of dirt, querying the number of properties in the Shell Point area near Shell Point Park that would be able to take advantage of this text amendment considering it must be a 3-acre or larger property *(Mr. Merchant noted that very few lots will be involved.)*, consider changing the start time trucks can operate from 7:00 a.m. to 9:00 a.m. in residential area or wherever school children must wait for school buses, recommending a provision to take the Clemson Extension Master Pond Management classes where proper safety and safeguards are taught, and belief that such a provision would not be used by property owners of a 1-acre pond.

Public Comment: None were received

Motion: Mr. Jason Hincher made a motion, and Mr. Robert Semmler seconded the motion, **to recommend approval to County Council on the Text Amendments to the Beaufort County Community Development Code (CDC): Article 4, Section 4.2.20 General Standards and Limitations, T3-Neighborhood that will allow private fish ponds with the conditions recommended by the staff.** Further discussion included not including the requirement for pond management training, and staff providing clarification on private fish ponds for personal use. The motion failed **(FOR: Chmelik and Hincher; AGAINST: Fermin, Pappas, Semmler, and Stewart; ABSENT: Mitchell; VACANCIES: St. Helena Island and Southern Beaufort County (Walsnovich) and Fireall).**

STAFF REPORT:

A. BACKGROUND:

Case No.	ZTA 2017-13
Applicant:	Greg Humphries
Proposed Text Change:	Text Amendment to the Beaufort County Community Development Code (CDC): Article 4, Section 4.2.20 General Standards and Limitations, T3 Neighborhood (to allow private fish ponds).

B. SUMMARY OF REQUEST:

The Community Development Code allows private fish ponds of one acre or less as an accessory use to a residential dwelling in the T2 districts and C3-Neighborhood Mixed-Use. The applicant is requesting to allow private fish ponds in the T3 Neighborhood District as well.

Where private fish ponds are permitted, Article 4, Section 4.2.200 places specific restrictions on their size and location:

- The minimum lot size where a fish pond can be located is 3 acres.
- Fish ponds can be no greater than 1 acre in size.
- Ponds shall be setback a minimum of 100 feet from the OCRM critical line, if applicable; and
- Ponds shall be excavated no deeper than 12 feet from existing grade with safe edges (minimum slope of 1:5 to a depth of three feet).

In addition, there are specific requirements that apply to the excavation process. Excavation activities are limited to 7:00 a.m. to 6:00 p.m. Monday through Saturday, and maximum noise at the property line cannot exceed 65 decibels. There are restrictions on hauling fill dirt through residential neighborhoods with the property owner responsible for damage to roads caused by truck traffic related to the excavation of the pond. If fill dirt leaves the site or is sold, the property owner shall submit a valid mining permit issued by the appropriate state agency at the time of application for a private fish pond.

C. ANALYSIS: Sec. 7.7.30(C). Code Text Amendment Review Standards. The advisability of amending the text of this Development Code is a matter committed to the legislative discretion of the County Council and is not controlled by any one factor. In determining whether to adopt or deny the proposed text amendment, the County Council shall weigh the relevance of and consider whether, and the extent to which, the proposed amendment:

1. **Is consistent with the goals, objectives, and policies of the Comprehensive Plan:** The issue of private fish ponds is not directly addressed in the Comprehensive Plan.
2. **Is not in conflict with any provision of this Development Code or the Code of Ordinances:** See item #5.
3. **Is required by changed conditions:** Not applicable.
4. **Addresses a demonstrated community need:** Not applicable
5. **Is consistent with the purpose and intent of the zones in this Development Code, or would improve compatibility among uses and ensure efficient development within the County:** The T3 Neighborhood District is intended to provide moderate density residential development within walking distance to transit and commercial areas. For this reason, the district has a *maximum* lot size of 20,000 square feet. The required minimum lot size would limit private ponds to lots of record of 3 acres or greater. This restriction would limit any adverse impacts on the intent of the T3 Neighborhood district. Additionally, the restrictions placed on the excavation of the pond and the removal of dirt should address adverse impacts to neighboring properties.
6. **Would result in a logical and orderly development pattern:** See item #5.
7. **Would not result in adverse impacts on the natural environment, including but not limited to water, air, noise, stormwater management, wildlife, vegetation, wetlands, and the natural functioning of the environment:** It is staff's opinion that the natural resource protection, stormwater and performance standards in the CDC will minimize impacts to the environment.

D. RECOMMENDATION: Staff recommends approval with the following conditions:

- Private fish ponds should be permitted in all T3 districts (see attachment).
- Since this amendment may result in a greater number of fish ponds in residential areas, the conditions in Section 4.2.200 should be strengthened to require a truck routing plan and greater safeguards if roadways are damaged. The following language is proposed for 4.2.200.I:

  I. Truck Routing Plan. *A truck routing plan shall be submitted that ensures that truck traffic through residential areas is avoided or mitigated to the extent practicable. Any roads brought to sub-standard condition due to work on the site as determined by SCDOT and/or the County must be brought up to standard. At a minimum, a road must be returned to its initial condition.*

E. ATTACHMENTS:

- Application
- Proposed changes to the CDC

Table 4.2.20A: Table of Permitted Accessory Uses																	
Accessory Use/ Structure Type	**Additional Requirements**	**T1 N**	**T2R T2RL**	**T2 RN**	**T2 RNO**	**T2 RC**	**T3E**	**T3 HN**	**T3 N**	**T4 HC**	**T4 VC**	**T4 HCO**	**T4 NC**	**C3**	**C4**	**C5**	**SI**
Accessory / Secondary Dwelling Unit	4.2.30	--	P	P	P	P	P	P	P	P	P	P	P	P	--	--	--
Cottage Industry	4.2.40	--	P	--	P	P	--	--	--	--	--	--	--	--	--	--	--
Fences and Walls	4.2.50	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Food Sales (Indoor)	4.2.60	--	P	--	P	P	--	--	--	P	P	P	P	--	P	P	P
Freestanding Accessory Structure (includes Garages and Sheds)	4.2.20.E	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Guest House	4.2.70	--	P	P	P	P	P	P	--	--	--	--	--	P	--	--	--
Home Business	4.2.80	P	P	P	P	P	--	--	P	P	P	P	P	P	--	--	--
Home Office	4.2.90	--	P	P	P	P	P	P	P	P	P	P	P	P	--	--	--
Outdoor Display (as an Accessory Use)	4.2.100	--	--	--	P	P	--	--		--	P	P	P	--	P	P	--
Outdoor Storage (as an Accessory Use)	4.2.110	--	--	--	--	P	--	--	--	--	--	P	P	--	P	P	P
Private Fish Ponds	4.2.200	--	P	P	P	P	P	P	P	--	--	--	--	P	--	--	--
Private Stables	4.2.120	--	P	P	P	--	--	--	--	--	--	--	--	P	--	--	--
Satellite Dish Antenna	4.2.130	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Security Quarters	4.2.140	--	--	--	--	P	--	--	--	--	P	P	P	--	P	P	P
Small Wind Energy System	4.2.150	P	P	P	P	P	--	--	--	--	--	--	--	--	--	--	P
Solar Energy Equipment	4.2.160	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Swimming Pools, Hot Tubs, and Ornamental Ponds and Pools	4.2.170	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Waste Receptacles and Refuse Collection Areas	4.2.180	--	P	P	P	P	--	--	P	P	P	P	P	P	P	P	P
Water/Marine-Oriented Facilities	4.2.190	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

P=Permitted Subject to the Additional Requirements --=Not Allowed

4.2.200 Private Fish Ponds

A Private Fish Pond shall comply with the following standards:

A. **Zones Allowed.** Private fish ponds shall be permitted as an accessory use to a principal residential dwelling unit in accordance with Table 4.2.20 (Table of Permitted Accessory Uses).

B. **Size/Area.**

1. Ponds are permitted to be excavated on lots a minimum of three acres in size.

2. Ponds shall be no larger than one acre in size.

C. **Setbacks.** All excavation activities shall meet all setbacks applicable to the principal structure, except that these activities shall be set back a minimum of 100 feet from the OCRM critical line, if applicable.

D. **Maximum Depth of Excavation.** Ponds shall be excavated no deeper than 12 feet from existing grade.

E. **Safe Edges.** Safe edges shall be provided for any excavation on the site to prevent accidents. Safe edges shall require a long shelf with a slope a minimum of 1:5 to a depth of three feet.

F. **Engineer's Report Required for Disturbance Greater than 10,000 Square Feet.** Any private pond excavation resulting in a land disturbance of 10,000 sq. ft. or greater shall provide a certified engineer's report ensuring that drainage and runoff do not adversely impact the property or surrounding properties.

G. **Hours of Operation.** Excavation activities are limited to 7:00 a.m. to 6:00 p.m. Monday through Saturday.

H. **Noise.** Maximum noise at the property line shall not exceed 65 decibels.

I. **Truck Routing Plan ~~Haul Route~~.** ~~The hauling of fill dirt through existing residential areas should be avoided, or the shortest route should be utilized. The property owner shall be responsible for damage to roads caused by truck traffic related to the excavation of the pond.~~ A truck routing plan shall be submitted that ensures that truck traffic through residential areas is avoided or mitigated to the extent practicable. Any roads brought to sub-standard condition due to work on the site as determined by SCDOT and/or the County must be brought up to standard. At a minimum, a road must be returned to its initial condition.

J. **State Permit Required if Fill Dirt Leaves the Site or is Sold.** If fill dirt leaves the site or is sold, the property owner shall submit a valid mining permit issued by the appropriate state agency at the time of application for a private fish pond.

BEAUFORT COUNTY, SOUTH CAROLINA
PROPOSED COMMUNITY DEVELOPMENT CODE (CDC)
ZONING MAP OR TEXT AMENDMENT / PUD MASTER PLAN CHANGE APPLICATION

TO: Beaufort County Council

The undersigned hereby respectfully requests that the Beaufort County Zoning/Development Standards Ordinance (ZDSO) be amended as described below:

1. This is a request for a change in the (check as appropriate): ( ) PUD Master Plan Change
( ) Zoning Map Designation/Rezoning (✓) Community Development Code Text

2. Give exact information to locate the property for which you propose a change:
Tax District Number: 100, Tax Map Number: 34, Parcel Number(s): 0020
Size of subject property: 369,444 SF / 8.48 Ac Square Feet / Acres (circle one)
Location: 615 BROAD RIVER DRIVE IN SHELL POINT

3. How is this property presently zoned? (Check as appropriate)
( ) T4NC Neighborhood Center
( ) T4HC Hamlet Center
( ) T4HCO Hamlet Center
( ) T4VC Village Center
(✓) T3N Neighborhood
( ) T3HN Hamlet Neighborhood
( ) T3E Edge
( ) T2RC Rural Center
( ) T2RN Rural Neighborhood
( ) T2RNO Rural Neighborhood Open
( ) T2R Rural
( ) T1 Natural Preserve
( ) Community Preservation (specify)________
( ) C3 Neighborhood Mixed Use
( ) C4 Community Center Mixed Use
( ) C5 Regional Center Mixed Use
( ) S1 Industrial
( ) Planned Unit Development/PUD (name)________

4. What new zoning do you propose for this property? N/A
(Under Item 9 explain the reason(s) for your rezoning request.)

N/A 5. Do you own all of the property proposed for this zoning change? ( ) Yes ( ) No
Only property owners or their authorized representative/agent can sign this application. If there are multiple owners, each property owner must sign an individual application and all applications must be submitted simultaneously. If a business entity is the owner, the authorized representative/agent of the business must attach: 1- a copy of the power of attorney that gives him the authority to sign for the business, and 2- a copy of the articles of incorporation that lists the names of all the owners of the business.

6. If this request involves a proposed change in the Community Development Code text, the section(s) affected are: 4.2.20 GENERAL STANDARDS and LIMITATIONS, 4.2.200 PRIVATE FISH PONDS
(Under Item 9 explain the proposed text change and reasons for the change.)

N/A 7. Is this property subject to an Overlay District? Check those which may apply:
( ) MCAS-AO Airport Overlay District/MCAS
( ) BC-AO Airport Overlay District/Beaufort County
( ) CPO Cultural Protection
( ) CFV Commercial Fishing Village
( ) MD Military Overlay District
( ) RQ River Quality Overlay District
( ) TDR Transfer of Development Rights

8. The following sections of the Community Development Code (CDC) (see attached sheets) should be addressed by the applicant and attached to this application form:
   a. Division 7.3.20 and 7.3.30, Comprehensive Plan Amendments and Text Amendments.
   b. Division 7.3.40, Zoning map amendments (rezoning).
   c. Division 1.6.60, Planned Unit Developments (PUDs) Approved Prior to Dec. 8, 2014
   d. Division 6.3, Traffic Impact Analysis (for PUDs)

9. Explanation (continue on separate sheet if needed): APPLICANT IS REQUESTING A TEXT AMENDMENT TO ALLOW A PRIVATE FISH POND TO BE CONSTRUCTED IN T3N ZONING

It is understood by the undersigned that while this application will be carefully reviewed and considered, the burden of proof for the proposed amendment rests with the owner.

[signature] 8/11/17

Signature of ~~Owner~~ AGENT (see Item 5 on page 1 of 2) Date

Printed Name: Greg Humphries Telephone Number: 843-816-8103

Address: 1850 Ribaut Rd Port Royal SC 29935

Email: lowcoast@embarqmail.com

Agent (Name/Address/Phone/email): ______

UPON RECEIPT OF APPLICATIONS, THE STAFF HAS THREE (3) WORK DAYS TO REVIEW ALL APPLICATIONS FOR COMPLETENESS. THE COMPLETED APPLICATIONS WILL BE REVIEWED FIRST BY THE BEAUFORT COUNTY PLANNING COMMISSION SUBCOMMITTEE RESPONSIBLE FOR THE AREA WHERE YOUR PROPERTY IS LOCATED. MEETING SCHEDULES ARE LISTED ON THE APPLICATION PROCESS (ATTACHED). COMPLETE APPLICATIONS MUST BE **SUBMITTED BY *NOON* THREE WORKING DAYS AND FOUR (4) WEEKS PRIOR FOR PLANNED UNIT DEVELOPMENTS (PUDs) OR THREE (3) WEEKS PRIOR FOR NON-PUD APPLICATIONS** TO THE APPLICABLE PLANNING COMMISSION MEETING DATE.

PLANNED UNIT DEVELOPMENT (PUD) APPLICANTS ARE REQUIRED TO SUBMIT FIFTEEN (15) COPIES TO THE PLANNING DEPARTMENT. CONSULT THE APPLICABLE STAFF PLANNER FOR DETAILS.

FOR MAP AMENDMENT REQUESTS, THE PLANNING OFFICE WILL POST A NOTICE ON THE AFFECTED PROPERTY AS OUTLINED IN DIV. 7.4.50 OF THE COMMUNITY DEVELOPMENT CODE.

CONTACT THE PLANNING DEPARTMENT AT (843) 255-2140 FOR EXACT APPLICATION FEES.

FOR PLANNING DEPARTMENT USE ONLY:

Date Application Received:
(place received stamp below)

Date Posting Notice Issued:

Application Fee Amount Received:

Receipt No. for Application Fee:

CAROLINA ENGINEERING
CONSULTANTS, INC.

P.O. Box 294
Beaufort, SC 29901

(843) 322-0553
(843) 322-0556 Fax

August 9, 2017

Mrs. Delores Frazier
Beaufort County Planning Dept
PO Drawer 1228
Beaufort SC 29901-1228

RE: Text Amendment for Private Fish Pond in T3N Zoning
615 Broad River Drive
Shell Point
Job No. 2066

Dear Delores:

In support of our request for a Text Amendment to allow a Private Fish Pond in T3N zoning, please find enclosed the following:

1. The $250 Application fee
2. One (1) copy of the Text Amendment Application
3. One (1) copy of the Conceptual Pond Plan

Mr. Trey Smith (the owner of the 8.5 acres at 615 Broad River Blvd.) and I met with the County Staff on July 19th to discuss the possibility of Mr. Smith being able to dig a 1.0 acre private fish pond on his property. We were informed at the meeting that a Text Amendment in the Beaufort County Community Development Code would be required in order for Mr. Smith to dig his pond. Mr. Smith, his wife, and his four (4) sons currently live in a house on the property.

The Beaufort County Community Development Code currently allows private fish ponds as an accessory use to a principal residential dwelling unit in several zoning districts, as long as the property is at least 3.0 acres in size and the pond is no larger than 1.0 acres in size. Mr. Smith's property meets all of the criteria except for its zoning. His property is currently zoned T3N.

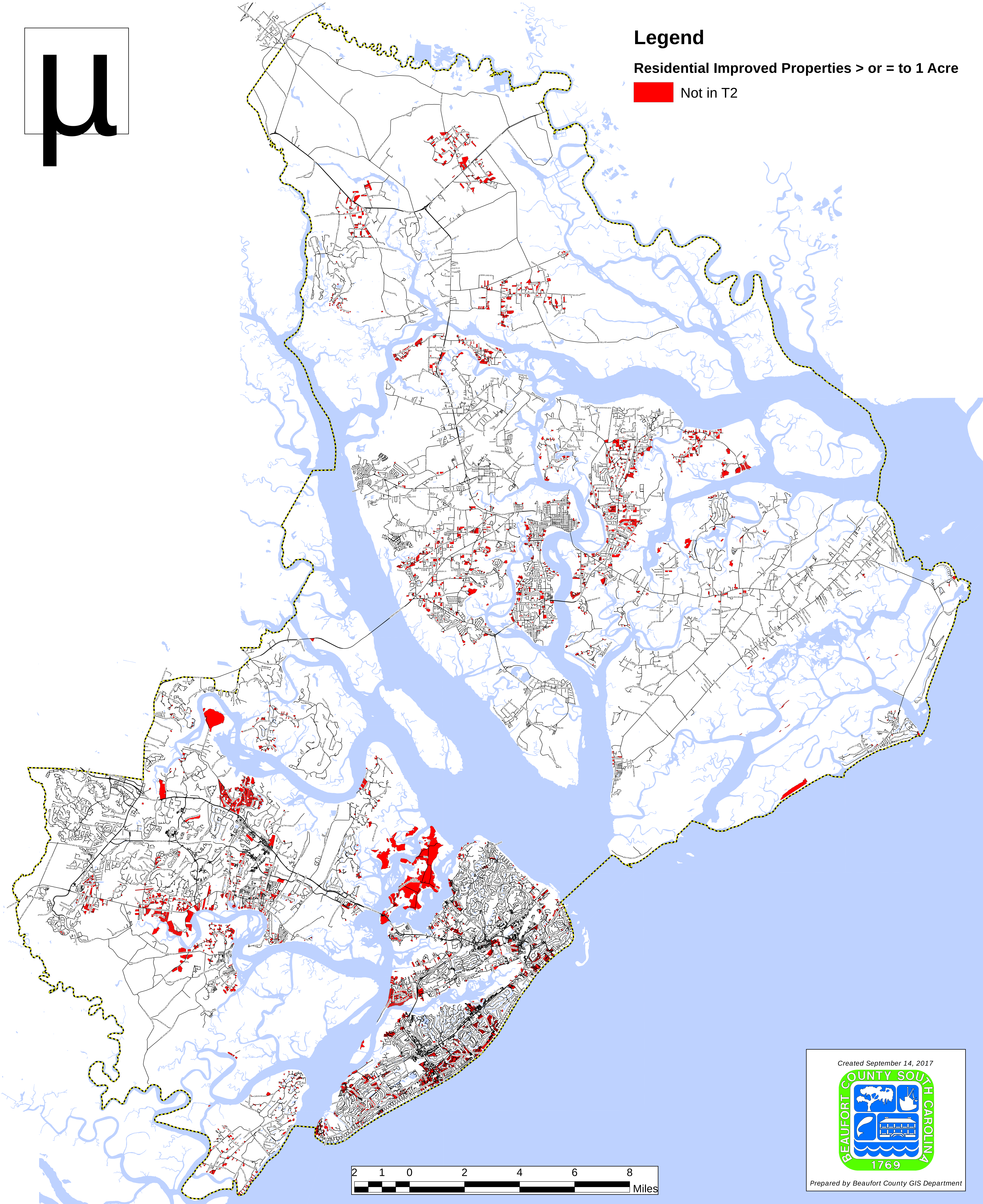
Mr. Smith's property is currently bordered by Beaufort County parks to the North, East and West and undeveloped property to the South. It would not be a detriment to the adjacent property owners or his community, and it would give his sons a place to fish and enjoy nature and wildlife on the property where they live.

Mrs. Delores Frazier
August 9, 2017
Page Two

We are requesting the County's review and approval of our request to dig a 1.0 acre private fish pond in the T3N zoning district. If you have any questions or require any additional information to complete your review, please feel free to give me a call at our office.

Sincerely,

David R. Karlyk, PE
Carolina Engineering Consultants, Inc.



Legend
Residential Improved Properties > or = to 1 Acre
Not in T2
2 1 0 2 4 6 8
Miles
Created September 14, 2017
BEAUFORT COUNTY SOUTH CAROLINA
1769
Prepared by Beaufort County GIS Department

2017 /

TEXT AMENDMENTS TO THE BEAUFORT COUNTY COMMUNITY DEVELOPMENT CODE (CDC), ARTICLE 5 (SUPPLEMENT TO ZONES), DIVISION 5.5 (OFF-STREET PARKING), SECTION 5.5.30.A. STORAGE AND/OR PARKING OF HEAVY TRUCKS AND TRAILERS

Whereas, amended text is highlighted in yellow, underscored for additions and struck through for deletions.

Adopted this _____ day of _____, 2017.

COUNTY COUNCIL OF BEAUFORT COUNTY

BY:_______________________________________

D. Paul Sommerville, Chairman

APPROVED AS TO FORM:

____

Thomas J. Keaveny, II, Esquire
Beaufort County Attorney

ATTEST:

____

Ashley M. Bennett, Clerk to Council

First Reading: August 28, 2017
Second Reading:
Public Hearing:
Third and Final Reading:

ARTICLE 5. SUPPLEMENT TO ZONES

DIVISION 5.5: Off-Street Parking

5.5.30 General Parking Standards

A. **Storage and/or Parking of Heavy Trucks~~,~~ and Trailers~~, Recreational Vehicles, Boats, Campers, and similar Vehicles~~.** Parking or storage of heavy trucks (vehicles over 20,000 GVW)~~,~~ and trailers~~, recreational vehicles, boats, campers, or similar vehicles~~ in any zone for residential or storage purposes shall be prohibited except as follows:

1. Semi-trailer trucks, their cabs or trailers, and other heavy trucks may ~~shall not~~ be parked or stored on any residential lot ~~except~~ within the T2 Rural district.
2. In all other districts, one commercial truck or one semi-trailer cab may be parked on any residential lot of one acre or larger provided it is not prohibited by private covenants and restrictions.
3. Where storage and/or parking of heavy trucks and trailers is permitted, the following shall apply:
   a) The vehicle shall be stored in the rear or interior side setback behind the front of the building, garage, or carport;
   b) There is a principal use of the property, to which such storage would be an accessory use;
   c) No living quarters shall be maintained or any business conducted from within while such trailer or vehicle is so parked or stored; and
   d) The required number of parking spaces on the parcel is maintained in addition to the area used for the stored vehicle(s).

Notes:

- ***5.5.30.A.4. & 5. are incorporated in 5.5.30.A.3.***
- ***5.5.30.B & C are not affected***

ADD-ONS

The document(s) herein were provided to Council for information and/or discussion after release of the official agenda and backup items.

Topic:	Update / Southern Beaufort County Corridor Beautification Board
Date Submitted:	September 18, 2017
Submitted By:	Glen Stanford
Venue:	Natural Resources Committee

Topic: Update / Southern Beaufort County Corridor Beautification Board
Date Submitted: September 18, 2017
Submitted By: Glen Stanford
Venue: Natural Resources Committee

THE SOUTHERN BEAUFORT COUNTY CORRIDOR BEAUTIFICATION BOARD

Status Report and Update 9-18-17

- Board created 2013
- Master Plan
  - Beautify the median on Hwy 278 from Hwy 170 to the bridges to Hilton Head Island
  - Landscape design by JK Tiller Assoc
- First Project – Belfair Plantation segment
  - $86,000 financed with tree mitigation funds from the "Tree Fund"
  - Completed Spring 2015
- Second Project – Belfair to Rose Hill
  - $100,000 from "Tree Fund"
  - Completed Winter 2016

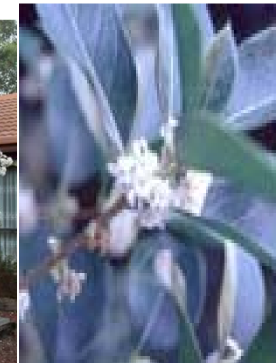

For Lease

Status Report (continued)

- Tanger Project Segment
  - Financed through Tanger funds under Development Agreement for Tanger 1
- SCDOT obstacle
  - Revised “Draft” Design Standards
  - Delay of many months
  - Assistance from Senator Tom Davis
- Projected Installation: Late 2017







QUESTIONS ?








IMAGES: COURTESY OF JK TILLER & ASSOC

Topic:	Digital Billboards - Public Safety / Emergency Management
Date Submitted:	September 18, 2017
Submitted By:	Michael Ruthsatz
Venue:	Natural Resources Committee

PUBLIC SAFETY / EMERGENCY MANAGEMENT

Topic: Digital Billboards - Public Safety / Emergency Management
Date Submitted: September 18, 2017
Submitted By: Michael Ruthsatz
Venue: Natural Resources Committee

Digital Messaging and Community Benefits

Adams Outdoor Advertising can help Beaufort County by partnering with local and national security and safety agencies to post urgent public safety messages, such as:

- Amber Alerts
- Severe Weather Advisories
- Hurricane Evacuation Routes
- Live Traffic Updates via RSS feed
- Local Events
- Local Charities / Community Outreach

Digital Messaging and Safety

Numerous independent studies, commissioned at both the Federal and State level, confirm that there is no significant relationship between digital messaging and an increase in traffic accidents.

- A Federal Highway Administration Report dated December 30, 2013 found, among other things, that the presence of digital messaging is not related to an increase in traffic accidents.

- The engineering firm Tantala Associates, at the request of several state agencies, examined traffic accidents near digital messaging. The results were unequivocal: there is no correlation between digital messaging and traffic accidents.

LIGHTING / ENVIRONMENT

LEDs

High efficiency LEDs can last up to 10 times longer than traditional lighting sources, which reduces waste.

Recycling

Many of the components comprising an digital unit can be harvested and recycled when the sign is retired, including aluminum, copper, gold and polycarbonate.

Durability

Digital units are designed for the long haul, which is easier on landfills and saves energy.

Beaufort
County Map

LEGEND

Existing Billboard Locations

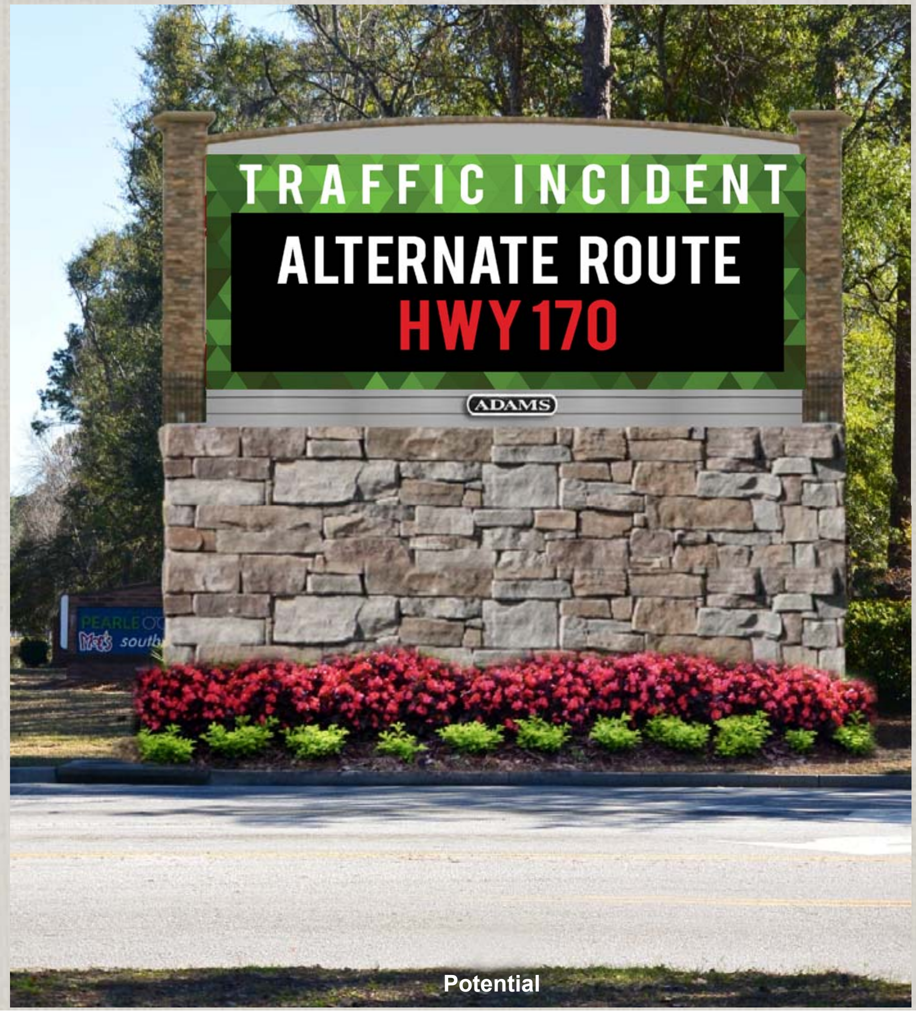
Potential Billboard Locations

Alternative Materials

- Stone
- Tabby
- Hardiplank
- Roofing
- Stucco - smooth


STORM ALERT
EVACUATE
NOW
ADAMS

Existing

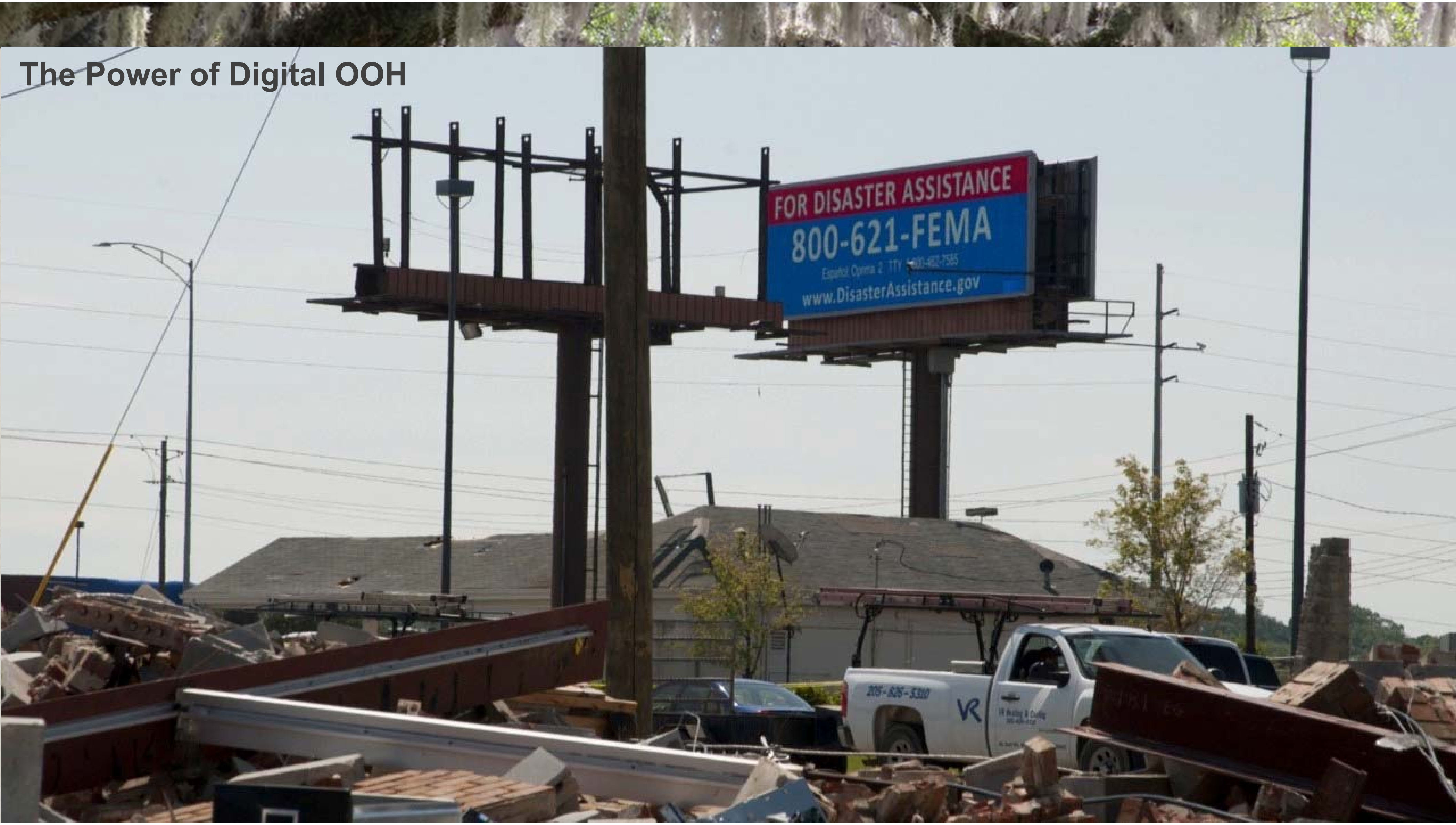


Potential

Existing

Potential

The Power of Digital OOH




THANK YOU
adams

Topic:	Study / Digital Billboards and Traffic Safety
Date Submitted:	September 18, 2017
Submitted By:	Michael Ruthsatz
Venue:	Natural Resources Committee

TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS

A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN HENRICO COUNTY AND RICHMOND, VIRGINIA

SUBMITTED TO

THE FOUNDATION FOR OUTDOOR ADVERTISING RESEARCH AND EDUCATION (FOARE)
1850 M STREET, NW, SUITE 1040
WASHINGTON, DC 20036-5821

BY

MICHAEL WALTER TANTALA, P.E.
ALBERT MARTIN TANTALA, SR., P.E.

ON

29 NOVEMBER 2010

TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
www.TANTALA.com

A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN HENRICO COUNTY AND RICHMOND, VIRGINIA

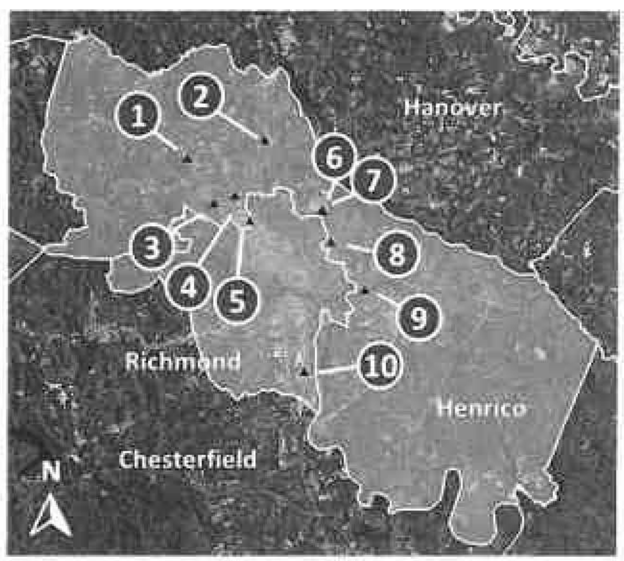
KEY POINTS

• More than 7 years of accident data comparisons

• Ten locations with 14 digital billboard faces with 10 second duration times

• Data show no statistically significant increase in accident rates, using before and after comparisons and using an Empirical Bayes Method Analysis for the actual and predicted comparisons

• Comparisons of driver age (young/elderly) and time of day (daytime/nighttime) are neutral factors



DIGITAL KEY

1 Rte 250 / West Broad Street
2 East Parham Road
3 Rte 250 / West Broad Street
4 Interstate 64
5 Interstate 195
6 East Laburnum Avenue
7 East Laburnum Avenue
8 Rte 360 / Mechanicsville Turnpike
9 Interstate 64
10 Interstate 95

Figure 1.
Digital Billboard Locations analyzed in Henrico County and Richmond, Virginia

More than 7 years of data ...

... no statistically significant relationship with the occurrence of accidents ...

... 10-second duration times ...

OVERVIEW

The purpose of this study is to **examine the statistical relationship between digital billboards and traffic safety in Henrico County and Richmond, Virginia**. This study analyzes traffic and accident data along routes near **10 locations with 14 digital billboard faces** (see Figure 1) with traffic volumes on roads collectively representing approximately 154 million vehicles per year. The study uses official data as collected, complied and recorded independently by municipal police departments, Henrico County and the Virginia Department of Transportation.

The study includes more than **seven years of accident data** representing approximately 40 thousand accidents near ten locations in Richmond and Henrico County. The billboards were converted to digital format between 2006 and 2009 and allow periods of comparison as long as 7.3 years (88 months).

Temporal (*when and how frequently*) and spatial (*where and how far*) statistics are summarized near billboards within multiple vicinity ranges as large as one-half mile for areas that are upstream and downstream of the billboards. Subsets of daytime and nighttime accidents and driver age are analyzed for before and after comparisons.

Additionally, an Empirical Bayes Method (EBM) analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of digital signs. This method is the basis of the safety analysis and science-based, predictive models introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14). This report establishes benchmarks for the basis of accident records at pre-digital locations and also uses other comparison sites in Henrico County and Richmond.

The overall conclusion of the study is that **the digital billboards in Richmond, Virginia have no statistically significant relationship with the occurrence of accidents**. This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. These conclusions are based on Police Department data and an objective statistical analysis; **the data show no significant increase in accident rates.**

DIGITAL KEY

1 Rte 250 / West Broad Street
2 East Parham Road
3 Rte 250 / West Broad Street
4 Interstate 64
5 Interstate 195
6 East Laburnum Avenue
7 East Laburnum Avenue
8 Rte 360 / Mechanicsville Turnpike
9 Interstate 64
10 Interstate 95

Figure 2.
Digital Billboard Locations analyzed in Henrico County and Richmond, Virginia. Each location studied has a 10 second duration time.

The static display on each of these digital billboards have "duration times" of 10 seconds.

STUDY REGION

This portion of the Greater Richmond Area was chosen as a study region, because it has multiple digital billboards in close proximity that were in service for extended periods of time. The roads adjacent to these billboards are heavily traveled (approximately 423 thousand vehicles traveled per day collectively on the sections of road near the digital billboards in Figure 2).

The study area of Henrico County and the City of Richmond, a portion of the Greater Richmond Area in Virginia, is situated in the central part of the State, and collectively has an area of approximately 308 square miles, has a population of 352 thousand people and has 174 thousand households (2000 census).

Several federal and state highways allow entry to the Greater Richmond Area as it is situated at the junction of east-west Interstate 64 and north-south Interstate 95, two of the most heavily traveled highways in the state. Henrico County is one of only two counties in Virginia that maintain their own roads. Interstate highways include Interstate 64, Interstate 95, and Interstate 295. Interstate 64 runs east-west and overlaps Interstate 95 for several miles in Richmond. Interstate 195 is a short spur from north of downtown Richmond, south into the downtown. Interstate 295 is a bypass to the east of Richmond and extends from Interstate 95 south of Petersburg. Other major highways include U.S. Route 1, U.S. Route 250 and U.S. Route 360.

BILLBOARD CHARACTERISTICS

Digital billboards display static messages which, when viewed, resemble conventional painted or printed billboards. With digital technology, a static copy displays for a duration and includes no animation, flashing lights, scrolling, or full-motion video. The static display of each of these digital billboards has a "duration time" of 10 seconds. The digital billboards use red, green, and blue light-emitting-diode (LED) technology to present text and graphics. The digital billboards compensate for varying light levels, including day and night viewing, by automatically monitoring and adjusting overall display brightness and gamma levels. A photocell is mounted on each digital billboard to measure ambient light. Each of the digital billboards that were studied is owned and operated by *Lamar*.

Billboard Location	Location	Configuration	Side of Road	Digital Facing Direction	Reader Side	Face Size (ft)	Duration Time (seconds)
1	**Rte 250 / West Broad Street** at 7912 West Broad Street (37° 37' 25.194", -77° 31' 40.515")	Free standing, Flag, Vee	N	E W	right cross	11x23 10.5x36	10 10
2	**East Parham Road** 0.25 miles west of Interstate 95 (37° 38' 6.7668", -77° 27' 40.381")	Free standing, Flag, Vee	N	W	cross	11x22	10
3	**Rte 250 / West Broad Street** at 5912 West Broad Street (37° 35' 32.607", -77° 30' 22.834")	Free standing, Center-mount with offset, Vee	N	E	right	11x23	10
4	**Interstate 64** 0.2 miles east of Staples Mill Road (37° 35' 49.729", -77° 29' 14.935")	Free standing, Center-mount, Vee	N	E	right	12.5x40	10
5	**Interstate 195** south of the Insterstates 64 and 95 intersection (37° 34' 45.757", -77° 28' 29.744")	Free standing, Flag, Vee	W	S N	cross right	14x36 14x36	10 10
6	**East Laburnum Avenue** 0.07 miles east of Carolina Avenue (37° 35' 7.3211", -77° 24' 48.898")	Free standing, Center-mount, Vee	N	E	right	10x21	10
7	**East Laburnum Avenue** 0.12 miles east of Carolina Avenue (37° 35' 7.3427", -77° 24' 45.050")	Free standing, Center-mount, Back-to-Back	N	E	right	10.5x36	10
8	**Rte 360 / Mechanicsville Turnpike** 0.3 miles north of Interstate 64 (37° 33' 50.011", -77° 24' 19.292")	Free standing, Center-mount, Back-to-Back	W	S N	cross right	14x28 14x28	10 10
9	**Interstate 64** 0.6 miles west of South Laburnum Avenue (37° 31' 50.091", -77° 22' 36.814")	Free standing, Center-mount, Vee	S	E	cross	12.5x42	10
10	**Interstate 95** 0.6 miles north of Bells Road / Rte 161 (37° 28' 32.231", -77° 25' 49.227")	Free standing, Center-mount, Vee	W	N S	right cross	14x48 14x48	10 10

Figure 3.
Digital Billboard Direction, Sizes and Other Sign Characteristics

Of the ten, digital-billboard locations studied, nine are located in Henrico County and one is located in the City of Richmond. Several additional digital locations were installed in the study region in 2010. These newer locations are not included as in this study because data collection would be limited to 2009; 2010 accident data was not available at the time of this study.

The digital, billboard locations are numbered 1 to 10 with 14 billboard faces. The ten locations in Henrico County and Richmond are shown in Figures 1, 2 and 3 which summarize direction, configuration and other sign characteristics. The digital boards and their surroundings were observed during day and night conditions. A majority of the digital billboards are freestanding single-pole, structures with one digital face; four locations have two digital boards on the same upright.

Figure 4 summarizes the conversion dates. Nine of the 14 billboard faces were converted to digital format prior to 2008 and the others were converted on various dates in 2008 and 2009. These dates allow for before/after comparisons as long as 7.3 years (or 88 months). Additional billboard-location photos, aerials, and map references for each digital location are included in this report as Figures 5 to 14.

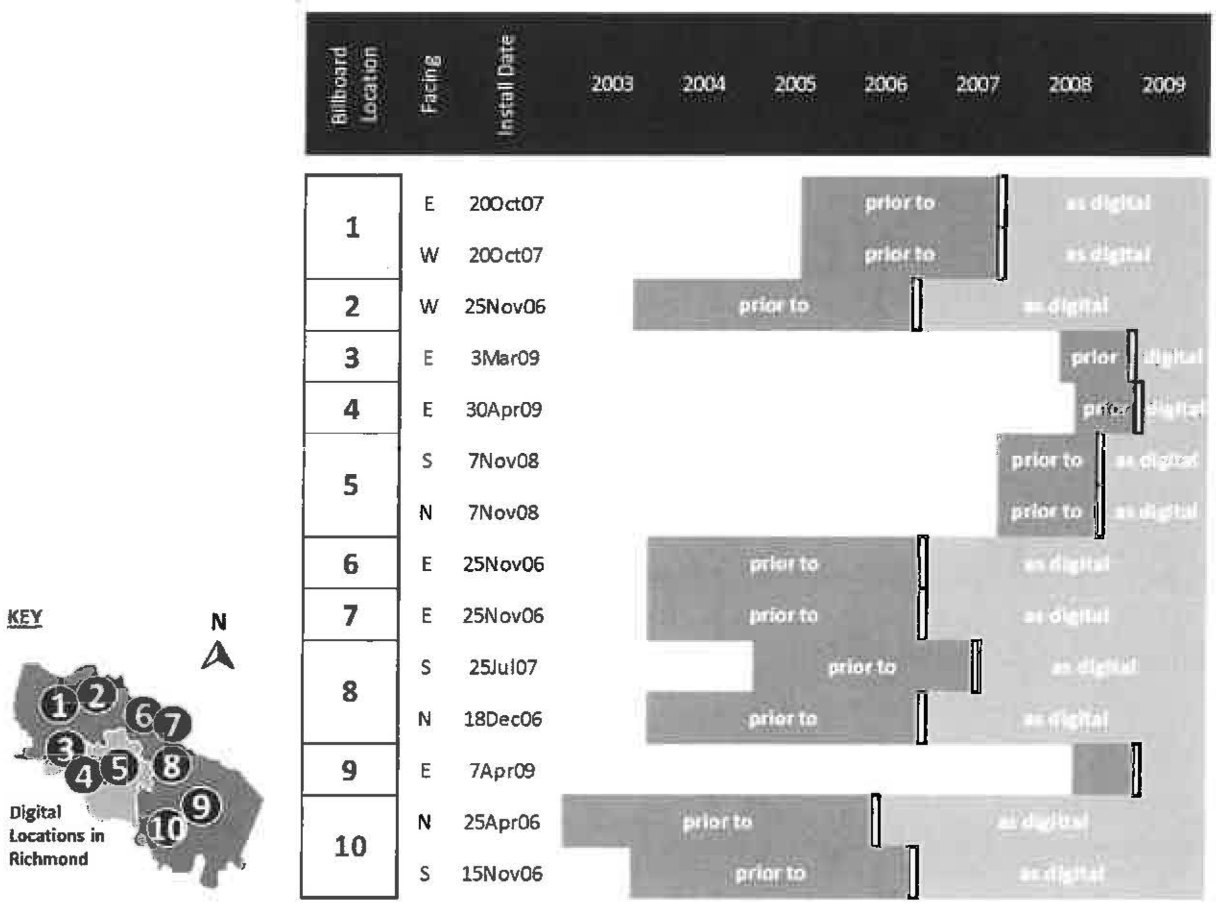


Figure 4.
Digital billboard Conversion Dates and Comparison Timelines for Digital Locations in Henrico County and Richmond, Virginia

Location No. 1 is on the north side of Route 250, at 7912 West Broad Street. The structure is a double-face, free standing, flag, vee configuration. The west face is a digital bulletin and is a right-hand reader. The west face (which faces east) has a 10.5x36 size and was a new build on 27Oct07 at this location. The east face (which faces west) is a digital poster and a cross reader. The east face has an 11x23 size and was a new build on 27Oct07. Each face is operated by Lamar, and has a duration time of 10 seconds. Figure 5a is a photo of the south digital face. Figure 5b shows the location in an oblique aerial.

Figure 5. Location No. 1 (5a, left) View on Route 250; inset shows opposite-face digital, (5b, right) Oblique Aerial of location

Location No. 2 is on the north side of East Parham Road, approximately 0.25 miles west of Interstate 95. The structure is a face, free standing, flag configuration. The east face is a digital poster and a cross reader. The face was converted from a conventional format on 25Nov06 using the existing location. The face is operated by Lamar, and has an 11x22 size with a duration time of 10 seconds. Figure 6a is a photo of the digital face. Figure 6b shows the location in an oblique aerial.

Figure 6. Location No. 2 (6a, left) View on East Parham Road North, (6b, right) Oblique Aerial of location

Location No. 3 is on the north side of Route 250, at 5912 West Broad Street. The structure is a double-face, free standing, center-mount with an offset, vee configuration. The west face is a digital poster and a right-hand reader. The north face was a new build on 3Mar09. The face is operated by Lamar, and has an 11x23 size with a duration time of 10 seconds. Figure 7a is a photo of the digital face. Figure 7b shows the location in an oblique aerial.

Figure 7. Location No. 3 (7a, left) View on Route 250, (7b, right) Oblique Aerial of location

Location No. 4 is on the north side of Interstate 64, approximately 0.2 miles east of Staples Mill Road. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital bulletin and a right-hand reader. The face was a new build on 30Apr09 at this location. The face is operated by Lamar, and has a 12.5x40 size with a duration time of 10 seconds. Figure 8a is a photo of the digital face. Figure 8b shows the location in an oblique aerial.

Figure 8. Location No. 4 (8a, left) View on Interstate 64, (8b, right) Oblique Aerial of location

Location No. 5 is on the west side of Interstate 195 just south of the intersection of the Interstate 64 and Interstate 95. The structure is a double-face, free standing, flag, vee configuration. The north face is a digital bulletin and a cross reader. The north and south faces were converted from conventional format on 7Nov08. Each face is operated by Lamar and has a 14x36 size with a duration time of 10 seconds. Figure 9a is a photo of the digital face. Figure 9b shows the location in an oblique aerial.

Figure 9. Location No. 5 (9a, left) View on Interstate 195, inset shows opposite-face digital (9b, right) Oblique Aerial of location

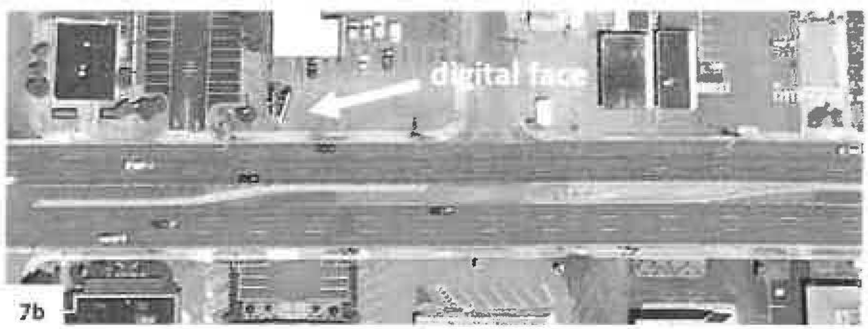

5a

5b


6a

6b


7a

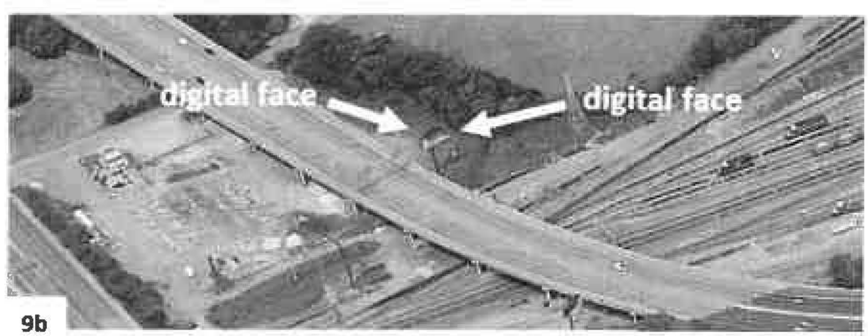


7b


8a

8b


9a



9b

Location No. 6 is on the north side of East Laburnum Avenue, approximately 0.07 miles east of Carolina Avenue. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital poster and a right-hand reader. The face was converted from a conventional format on 25Nov06 using the existing location. The face is operated by Lamar and has a 10x21 size with a duration time of 10 seconds. Figure 10a is a photo of the digital face. Figure 10b shows the location in an oblique aerial.

Figure 10. Location No. 6 (10a, left) View on East Laburnum Avenue, (10b, right) Oblique Aerial of location

Location No. 7 is also on the north side of East Laburnum Avenue, approximately 0.12 miles east of Carolina Avenue. The structure is a double-face, free standing, center-mount, back-to-back configuration. The west face is a digital poster and a right-hand reader. The west face was a new build on 25Nov06 at this location. The face is operated by Lamar and has a 10.5x36 size with a duration time of 10 seconds. Figure 11a is a photo of the digital face. Figure 11b shows the location in an oblique aerial.

Figure 11. Location No. 7 (11a, left) View on East Laburnum Avenue, (11b, right) Oblique Aerial of location

Location No. 8 is on the west side of the Route 360 (Mechanicsville Turnpike), approximately 0.3 miles north of Interstate 64. The structure is a double-face, free standing, back-to-back, center-mount configuration. The north face is a digital poster and a cross reader and was converted from a conventional format on 25Jul07. The south face is a digital poster and a right-hand reader. The south face was converted from a conventional format on 18Dec06. Each face is operated by Lamar and has a 14x28 size with a duration time of 10 seconds. Figure 12a is a photo of the digital face. Figure 12b shows the location in an oblique aerial.

Figure 12. Location No. 8 (12a, left) View at Route 360 (Mechanicsville Turnpike), inset shows opposite-face digital, (12b, right) Oblique Aerial of location

Location No. 9 is on the south side of Interstate 64, approximately 0.6 miles west of South Laburnum Avenue. The structure is a double-face, free standing, center-mount, vee configuration. The west face is a digital poster and a cross reader. The face is operated by Lamar, has a 12.5x42 size with a duration time of 10 seconds, and was converted on 7Apr09. Figure 13a is a photo of the east digital face. Figure 13b shows the location in an oblique aerial.

Figure 13. Location No. 9 (13a, left) View on Interstate 64, (13b, right) Oblique Aerial of location

Location No. 10 is on the west side of Interstate 95, approximately 0.6 miles north of Bells Road (Route 161). The structure is a double-face, free standing, center-mount, vee configuration. The south face is a digital poster and a right-hand reader. The south face was converted from a conventional format on 25Apr06. The north face is a digital poster and a cross reader. The north face was converted from a conventional format on 15Nov06 using the existing location. Each face is operated by Lamar and has a 14x48 size with a duration time of 10 seconds. Figure 14a is a photo of the digital face. Figure 14b shows the location in an oblique aerial.

Figure 14. Location No. 10 (14a, left) View on Interstate 95, inset shows opposite-face digital (14b, right) Oblique Aerial of location

10a

10b

11a

11b

12a

12b

13a

13b

14a

14b

AADT ranges individually near the 10 digital locations from 27 to 100 thousand vehicles per day, or equivalently 9 to 36 million vehicles per year.

TRAFFIC VOLUME DATA

Traffic volume data for Henrico County and Richmond were obtained from the Virginia Department of Transportation (VDOT) and include the annual average daily traffic (AADT), which is the average of 24-hour counts collected throughout the year. The AADT volumes were recorded for the Henrico County and Richmond between 2004 and 2009.

The AADT values are summarized in Figure 15. AADT ranges individually near the 10 digital locations from 27 to 100 thousand vehicles per day, or equivalently 9 to 36 million vehicles per year. For all locations, this collectively represents approximately 423 thousand vehicles per day or 154 million vehicles per year.

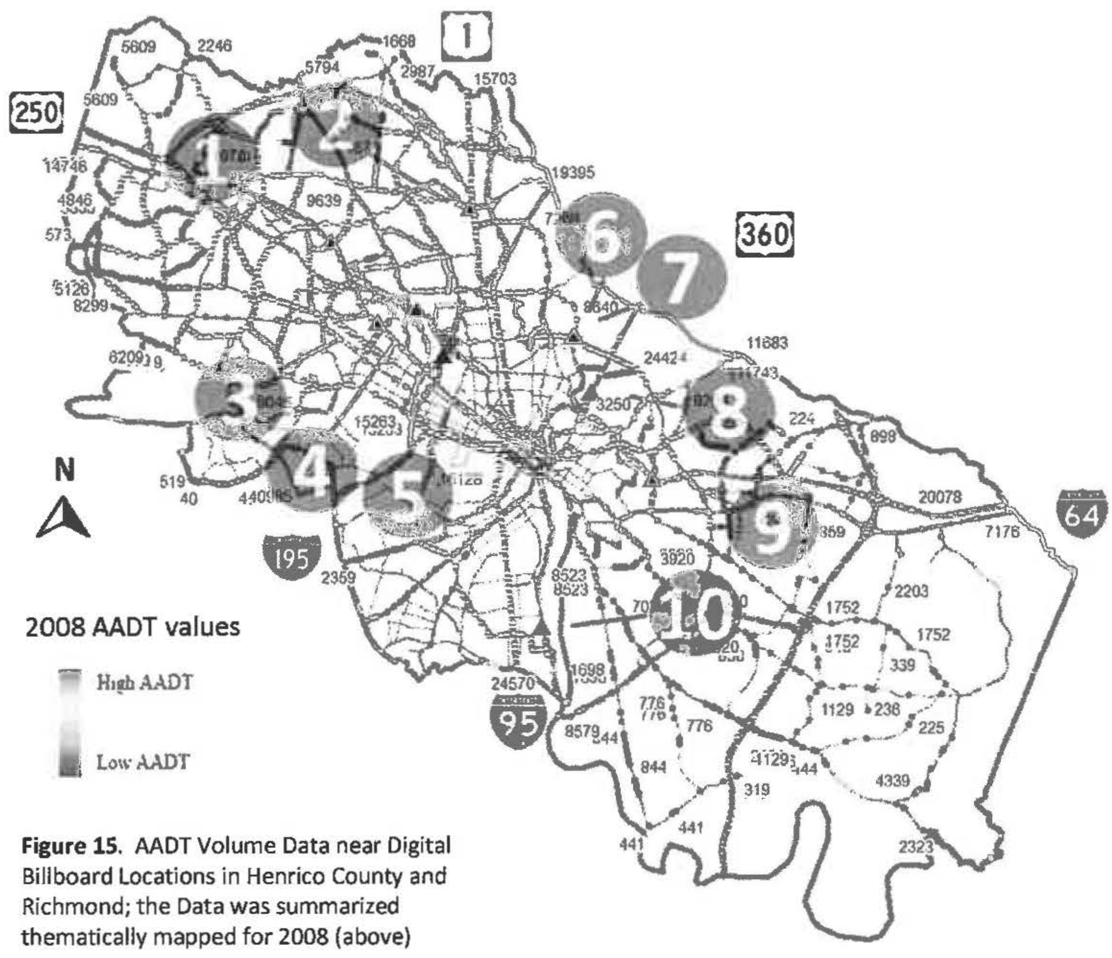


Figure 15. AADT Volume Data near Digital Billboard Locations in Henrico County and Richmond; the Data was summarized thematically mapped for 2008 (above)

ACCIDENT DATA

In this portion of the Greater Richmond Area, the majority of accident reports were investigated and recorded by each local and county Police Departments. Data were maintained by those Police Departments and compiled by the Virginia Department of Transportation. Law-enforcement officials are required to submit reports on crashes they investigate which meet reporting thresholds provided by statue, or in which someone was injured or killed. Data generally conform to the American National Standards Institute (ANSI) Standard D16.1 – 1996, Manual on Classification of Motor Vehicle Traffic Accidents.

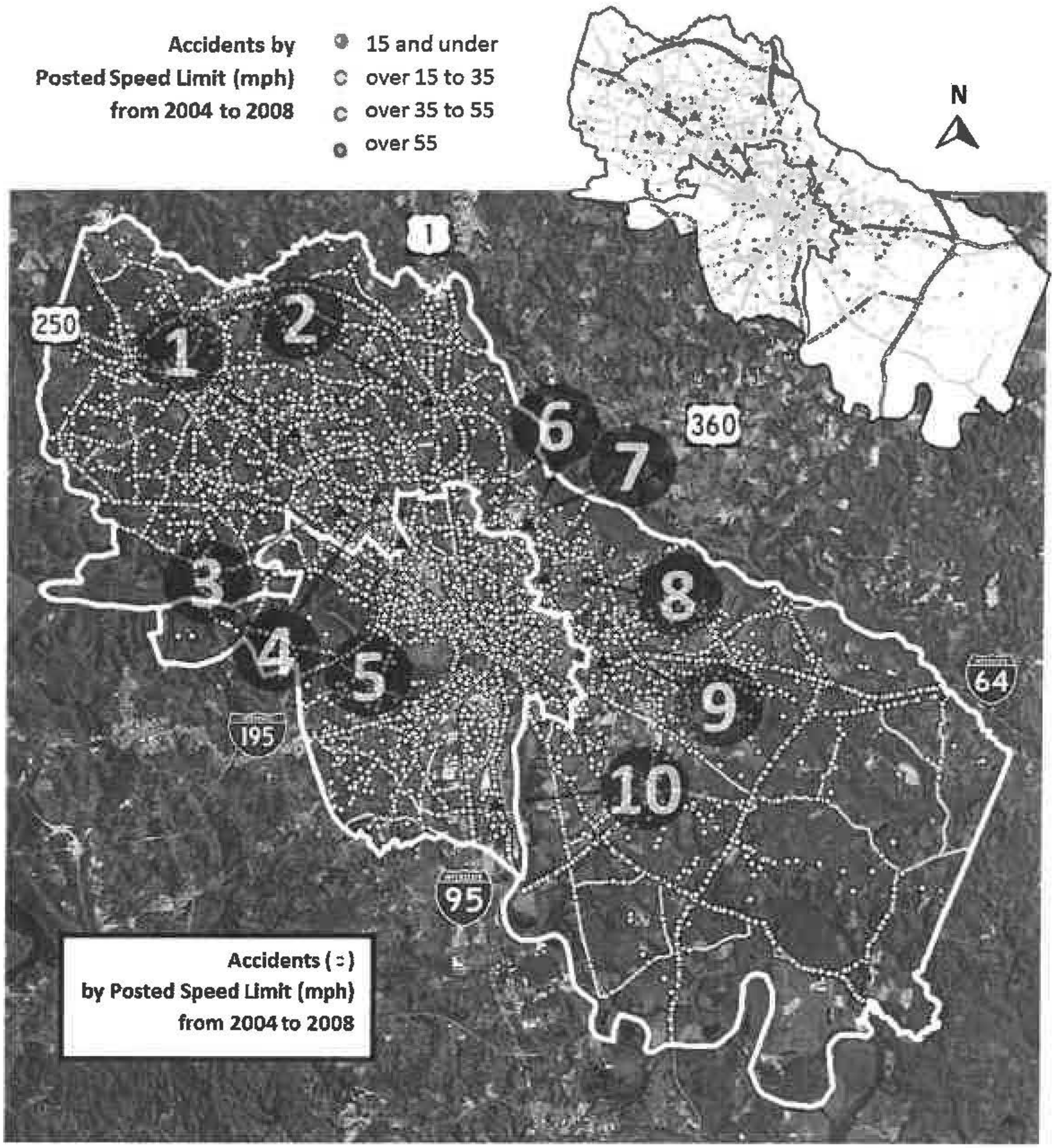


Figure 16. Traffic Accidents (yellow dots) near Digital Billboard Locations in Henrico County and Richmond, Virginia from 2004 to 2008; Inset shows Accident by Posted Speed Limit (mph)

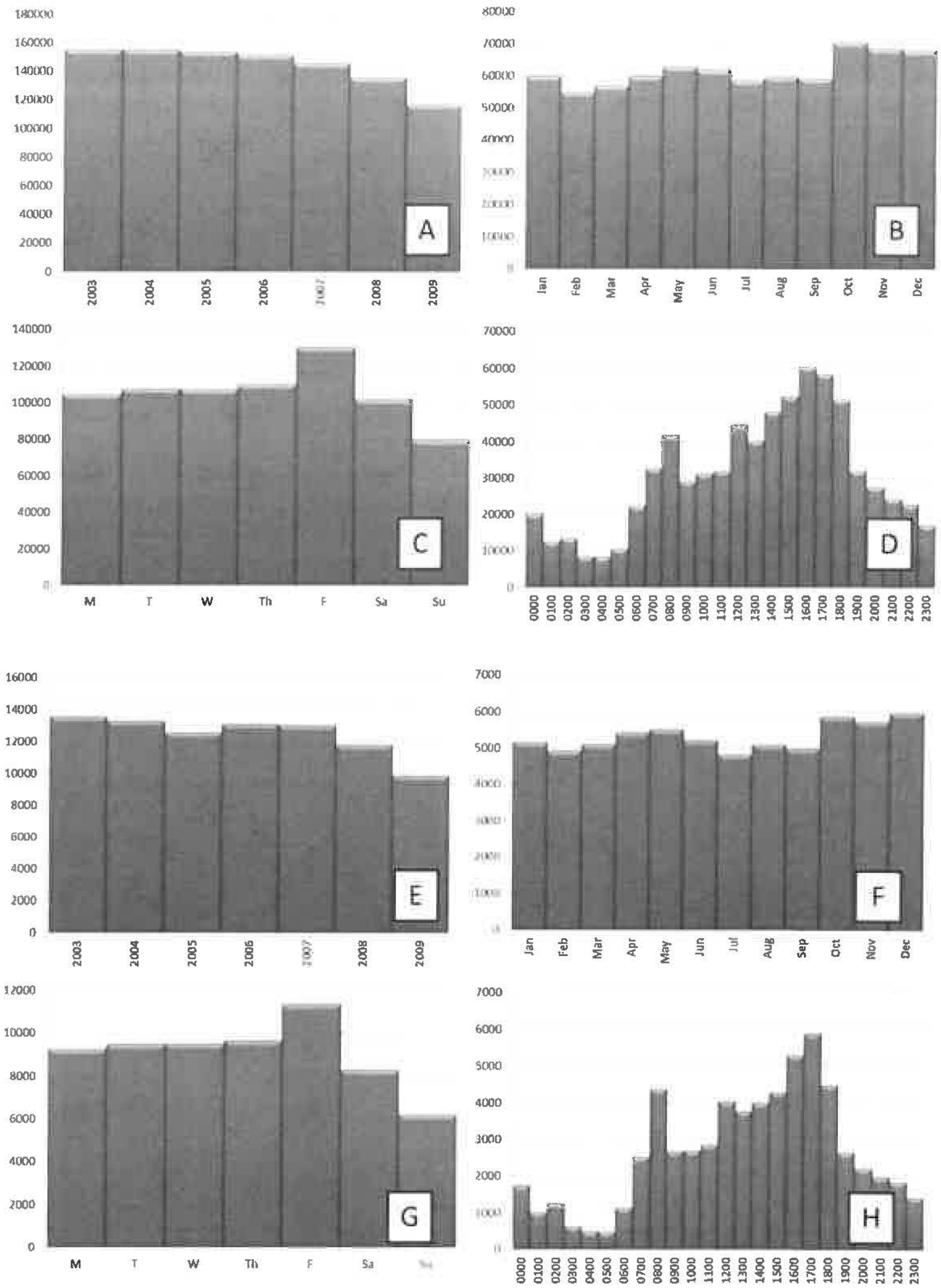


Figure 17. Histogram of Traffic Accident Data of the Past Seven Years in the State of Virginia (in blue) by Year (A), Month (B), Day of Week (C), and Time of Day (D) and in Henrico County and Richmond (in Red) by Year (E), Month (F), Day of Week (G), and Time of Day (H).

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 14 digital billboards faces were installed in Richmond.

The accident data-sets provided by VDOT include approximately 40,000 accidents during the seven years between 2004 and 2009 and near the digital billboard locations. Most of the data are specified by latitude and longitude or route nodes with offset distances. Figure 16 shows the geocoded accident locations generally within Henrico County and the City of Richmond.

Figure 17 summarizes the traffic accident data for the past seven years generally within the State of Virginia and within Henrico County and Richmond and show the distribution of accidents by year, month, day of week and time of day. This distribution represents a consistent pattern of data and illustrates that more accidents occur on weekdays and at rush hour (before and after work).

ANALYSIS

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 14 digital billboard faces were installed in Henrico County and Richmond.

The analysis has three parts.

Part 1 is a temporal analysis which compares *before* and *after* changes in crash rates and other metrics.

Part 2 is a spatial analysis which compares *where* and *how far* data to establish statistical correlation coefficients for various scenarios accounting for accident density and billboard proximity.

Part 3 uses the Empirical Bayes Method (EBM). This method uses the 'before' accident statistics to predict the number of accidents "expected" at the locations assuming that no digital billboard technology was introduced. The method is the basis of the safety analysis and science-based, predictive models introduced in the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14). We quantify what the actual 'after' accident statistics are and compare them with what the predicted values are from the EB analysis. This method analyzes data from the ten billboard location and incorporates data using non-digital comparison sites.

Analysis: Part 1 – Temporal Comparisons

The first part is a temporal analysis. The incidence of traffic accidents near the digital billboards is examined for an equal length of time before and after the digital billboards were installed and activated. This part is for the purpose of establishing if traffic accidents occurred more or less frequently in the presence of these digital billboards. With information collected from police accident reports, the temporal analysis also uses metrics such as traffic volumes, the accident-rate values, the maximum number of accidents during any given month, etc.

For comparison, accident statistics were summarized near the digital billboards within multiple vicinity ranges of 0.2, 0.4, 0.6, 0.8, and 1.0 miles both upstream and downstream of each billboard. For locations on local roads, these vicinity ranges also sampled data to include: (1) accidents along the principal roads to which the digitals directly advertise, (2) accidents recorded as occurring within the intersection of the primary road and any cross roads, and (3) for crossroad accidents within a reasonable distance from the primary road to include drivers turning onto or leaving the primary road. Accident data for roads to which the digitals do not advertise or are not connected were excluded, even if they were within the specified vicinity range.

Analysis: Part 2 – Spatial Comparisons

The second part is a spatial analysis. This establishes statistical correlation coefficients between the digital billboards and accidents. Correlation coefficients are statistical measures of the "association" between two sets of data. The results are analyzed for various scenarios accounting for accident density and billboard proximity.

Additionally, subsets of accident data for age of driver and for daytime and nighttime accidents are analyzed for before and after comparisons. For a more lengthy discussion of analysis methods, please refer to previous studies (see References 3 and 4).

Analysis: Part 3 – The Empirical Bayes Method (EBM)

The third part of the analysis uses the Empirical Bays Method (EBM).

An Empirical Bayes Method (EBM) analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of a digital sign.

Research literature suggests that the EBM method is appropriate for this type of analysis and is a widely accepted method in the field of traffic safety (see References 14 to 31). The method is the basis of the safety analysis and science-based, predictive models introduced within the 2010 *Highway Safety Manual* of the American Association of State Highway Official (AASHTO, Reference 14).

The negative binomial distribution is established by researchers as an accurate description of yearly crash variation between sites and was previously used to model and evaluate various transportation safety projects (see References 14 through 31). The correction for regression to the mean and the use of a negative binomial distribution are strengths of the EBM.

The EBM is used to estimate the number of crashes before the site change (i.e., before the introduction of digital technology). These "before" estimates are then used to predict the number of crashes that could be expected to occur at a certain location, during a specified year, without the introduction of digital technology.

The change in safety at a location is given as:

$$\Delta\, safety = B - A$$

where $\Delta\ safety$ is the change in the number of crashes, B is the expected number of crashes in the after period without the introduction of digital technology, and A is the actual number of crashes reported in the after period.

After identifying digital locations, a statistical crash estimate model (CEM) is developed. The CEM model is a multivariate, regression model used to estimate the mean and variance of the annual number of crashes that could be expected at each location. Various multivariate models were tested through an iterative process by fitting the available traits. The analysis uses a negative binomial distribution by fitting a generalized, linear model to the data by maximum likelihood estimation of the parameter vector, B.

The p-value is used as an indicator of the significance of the individual traits. The traits that produced a statistically sound model include the annual average daily traffic (AADT) for the location. The resulting CEM is then

$$P = \alpha_\lambda (AADT)^{\beta_1}\ (LANE)^{\beta_2} (Speed)^{\beta_3}.$$

The model parameters and the over-dispersion parameter (theta) are then calculated. The over-dispersion parameter is a measure of the extra variation in the negative binomial distributions compared to a traditional Poisson distribution; this parameter is commonly used in the calculation of the variance, or

$$variance = mean * \left(1 + \frac{mean}{\phi}\right).$$

Using the model, analyzed parameters and data, the expected number of crashes is estimated for each location, had no digital technology been introduced.

For each location, the first year for available data was used as a base year and a normalized mean number of crashes for each year, y is calculated as

$$C_y = \frac{P_y}{P_b}.$$

Where, P_y and P_b are the predicted total number of crashes from the CEM for the year y and the base year, respectively for each location. The projection of the number of crashes is independent of the choice of the base year.

The variance of the expected number of crashes, $Var(P)$ is calculated using the overdispersion parameter, as

$$Var(P) = (1 + \phi * P) * P.$$

The relative weight, α, is calculated as

$$\alpha = \frac{P}{Var(P)}.$$

Actual location crash counts, K, are then used to determine the EB estimate of mean and variance of the number of crashes for a site; EB and $Var(EB)$, respectively are

$$EB = \alpha * P + (1 - \alpha) * K, \text{ and}$$

$$Var(EB) = (1 - \alpha) * EB .$$

The projection of the expected "after" treatment number of crashes is based on the weighted average of the EB estimates of number of crashes of all "before" treatment years for conversion to digital technology.

The estimate of the baseline mean and the variance number of crashes, PC_b and $Var(PC_b)$ is determined as

$$PC_b = \frac{\sum_{before} EB}{\sum_{before} C_y}, \text{ and}$$

$$Var(PC_b) = \frac{\sum_{before} Var(EB)}{\left(\sum_{before} C_y\right)^2}.$$

The projected number of crashes for the conversion locations in the "after" conversion period is calculated by multiplying the normalized number of crashes/year, C_y, by the baseline projected number of crashes, PC_b. The mean and variance of the projected crash count in the "after" conversion period for year, y, B and $Var(B)$, are calculated as

$$B = C_y * PC_b, \text{ and}$$

$$Var(B) = C_y^2 * Var(PC_b).$$

The overall index of effectiveness, theta, is then calculated by comparing the total projected number of crashes (B) in the after period to the total actual number of crashes (A) in the after period as

$$\theta = \frac{\sum A}{\sum B}.$$

The unbiased estimate, θ_u, is then

$$\theta_u = \frac{\theta}{1 + \frac{\sum Var(B)}{(\sum B)^2}}.$$

The percent change in total crashes due to the introduction of digital technology is

$$\Delta\, crashes\,(\%) = (1 - \theta_u) * 100.$$

If the change of introducing digital technology causes crashes to be increased, then θ_u will be significantly larger than one and $\Delta\, crashes$ will be a negative value significantly lower than zero.

This analysis is applied to the data at 66 locations representing the 10 digital locations and 56 comparison sites.

The number of accidents and rates of accidents near the ten digital billboards locations remained consistent within all vicinity ranges.

RESULTS

Figure 18 shows a comparison of the accident metrics for before and after conversions near all ten digital billboards in Henrico County and Richmond, Virginia. The statistics are summarized for vicinity ranges of 0.2, 0.4, 0.6, 0.8, and 1.0 miles of the digital locations with 10 -second duration times collectively. The metrics in Figure 18 include the total number of accidents, the average number of accidents in any given month, the peak number of accidents in any given month, etc. Other metrics, including rates and vehicle-miles traveled were also analyzed.

For all locations (Figure 18), the number of accidents and rates of accidents near the ten, digital billboards decreased in all vicinity ranges. The benchmark, 0.6-mile vicinity experienced a 4.5% decrease in the number of accidents over the seven year span for all location; this includes a 9.5% decrease in accident rates per hundred thousand AADT vehicles.

Figure 19 shows the distributions of the number of accidents per month near digital billboards within the benchmark 1.0 mile vicinity between 2003 and 2009.

A statistical t-test is used to determine whether the average difference between the two, time periods is really significant or if it is due to random difference. Using a 95% confidence interval indicates that no statistically significant difference in the accident statistics evaluated between conventional and digital billboards at these digital locations.

Additionally, consistent results were obtained for driver-age comparisons. Low correlation coefficients were calculated for this spatial analysis. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near the digital billboards when compared with the accident patterns prior to conversion.

The statistical evaluation of the Empirical Bayes Method and results show that the total number of accidents is approximately equivalent to what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 66 locations within Henrico County and Richmond.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		Vicinity Range from Digital Location (miles)				
		0.2	0.4	0.6	0.8	1.0
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	241	648.75	832.25	1049.5	1243
	Average Number of Accidents per Month at Each Location	1.02	2.75	3.51	4.45	5.27
	Rate of Accidents per Vehicles (by hundred thousand AADT)	0.15	0.41	0.53	0.67	0.79
	Standard Deviation of Number of Accidents in any given month	1.82	4.01	4.97	5.89	6.84
	Peak Number of Accidents in any given Month per Location	11	19	26	28	35
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	52%	49%	40%	33%	33%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	205	617.25	795	977.25	1121
	Average Number of Accidents per Month at Each Location	0.89	2.67	3.44	4.23	4.85
	Rate of Accidents per Vehicles (by hundred thousand AADT)	0.12	0.37	0.48	0.59	0.68
	Standard Deviation of Number of Accidents in any given month	1.35	3.05	3.72	4.35	5.03
	Peak Number of Accidents in any given Month per Location	7.5	16	20	22	26.25
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	62%	52%	50%	42%	40%
Comparison	Change in Number of Accidents	-36	-31.5	-37.25	-72.25	-122
	Change in Average per Month	-0.13	-0.08	-0.08	-0.22	-0.41
	Change in Rate per vehicles (by hundred thousand AADT)	-0.03	-0.04	-0.05	-0.08	-0.12
	Percent Change in Number of Accidents	-14.9%	-5.0%	-4.5%	-6.9%	-9.8%
	Percent Change in Rate of Accidents	-19.4%	-10.0%	-9.5%	-11.8%	-14.6%

Figure 18. Summary of Accident Statistics within Vicinity Ranges near all Ten Digital-Billboards Locations with 10-second Duration Times in Henrico County and Richmond, Virginia

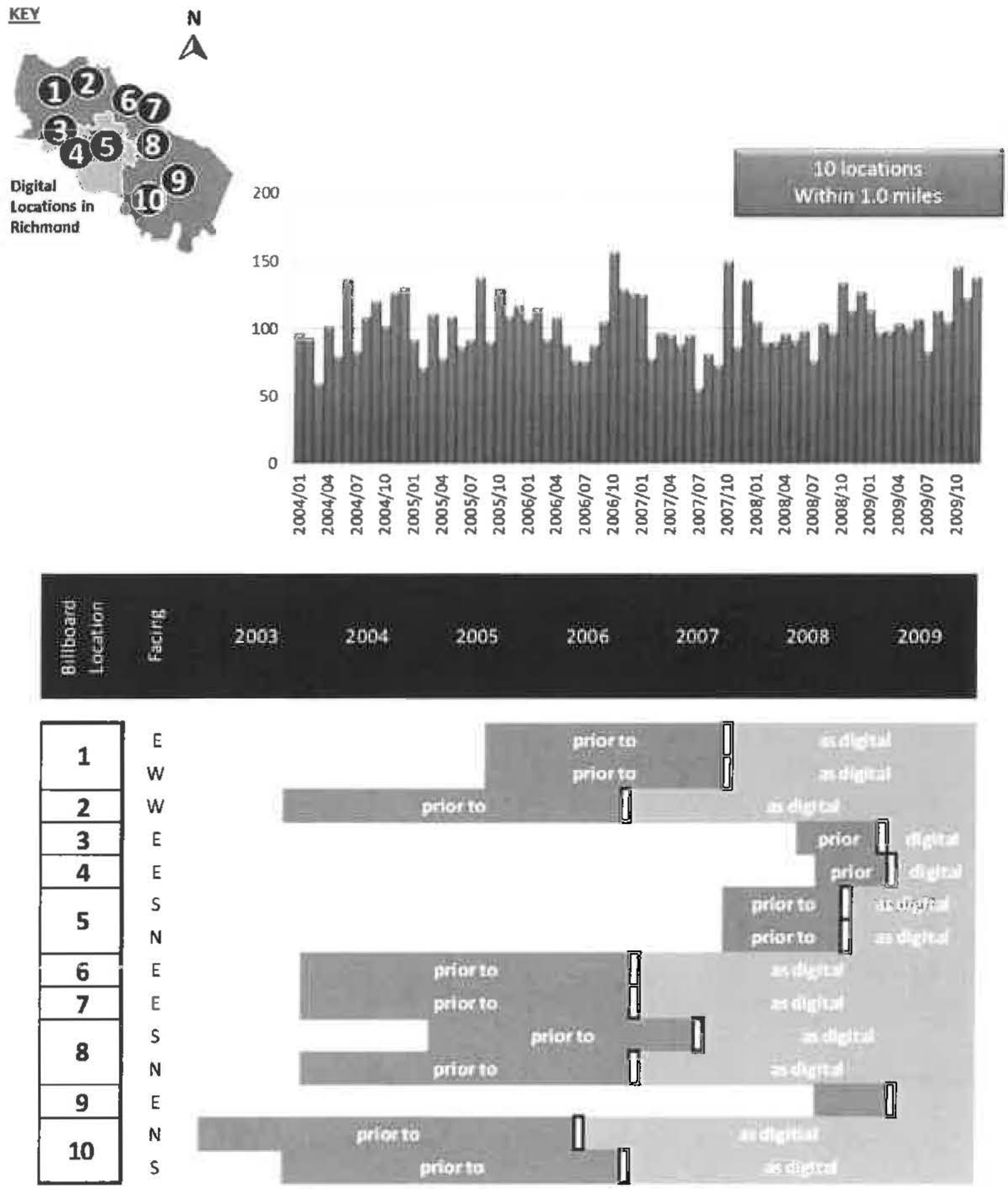


Figure 19. Distributions of the Number of Accidents per Month near Digital Billboards between 2004 and 2009, within a 1.0-mile Vicinity Range near all Digital Locations (top, red) compared with Conversion Dates and Before/After Comparison Periods

Figure 20 summarizes the accident rates that account for variations in traffic volumes for all digital locations within vicinity ranges of 0.2, 0.4, 0.6, 0.8, and 1.0 miles of the digital location. The 0.6 mile benchmark vicinity experienced a decrease in accident rates over the eight-year span. The change in accident rates decreased by 0.05 accidents per hundred thousand vehicles per year; a 9.5% decrease. Similar decreases and trends were observed for both smaller vicinity ranges.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		Vicinity Range from Digital Location (Miles)				
		0.2	0.4	0.6	0.8	1.0
Prior to Digital Location	Number of Accidents per million vehicles (by hundred thousand AADT)	0.15	0.41	0.53	0.67	0.79
As Digital Location	Number of Accidents per million vehicles (by hundred thousand AADT)	0.12	0.37	0.48	0.59	0.68
Comparison	Change in Rate per million vehicles (by hundred thousand AADT)	-0.03	-0.04	-0.05	-0.08	-0.12
	Percent Change in Rate of Accidents	-19.4%	-10.0%	-9.5%	-11.9%	-14.6%

Figure 20. Summary of Accident Rates within Vicinity Ranges near Ten Digital Billboards Locations 10- second-duration Times in Henrico County and Richmond, Virginia

COMPARISON OF ACCIDENTS BY AGE OF DRIVER

The accident statistics were also analyzed to determine if the age of the drivers involved in the accidents near the digital billboards was a factor. The data were specifically studied to determine if there are increases in the accident frequency of young drivers (under 17 and under 21) or elderly drivers (65 and older). Figure 21 summarizes the accidents and accident-rates by age of driver for all accidents.

Figure 22 shows the distributions of ages of driver for all accidents within Henrico County and Richmond (A, blue) and for all accidents within 1.0 miles of all digital locations (B, purple).

Figure 23 shows the distributions of driver ages within 1.0 miles of all digital locations for before (orange) and after (purple) periods of comparison. Figure 23 (left) also shows the correlation between before and after conversions for the number of accidents for each age. Individual accidents may have multiple cars and drivers involved, which is reflected in the analysis. In comparing the histograms in Figure 22 and 23, note the typical distribution type (shape) and typical average values. The mode driver age for accidents prior to digital conversion is 19 years; the mode drive age after conversions is 19 years.

Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for age-of-driver factors. Figure 23 shows a 0.920 (92.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		Crashes By Driver Age Group			
		under 17	under 21	21-65	over 65
[illegible]	Number of Accidents for equal periods prior to conversion	6	134	1007	97
As Digital Location	Number of Accidents for equal periods after conversion	6	98	922	95
Comparison	Change in Number of Accidents	None	36	85	2
	Percent Change in Number of Accidents	None	-26.9%	-8.4%	-2.1%

Figure 21. Summary of Accidents by Age Group within Vicinity Ranges near Ten Digital Billboard Locations in Henrico County and Richmond, Virginia

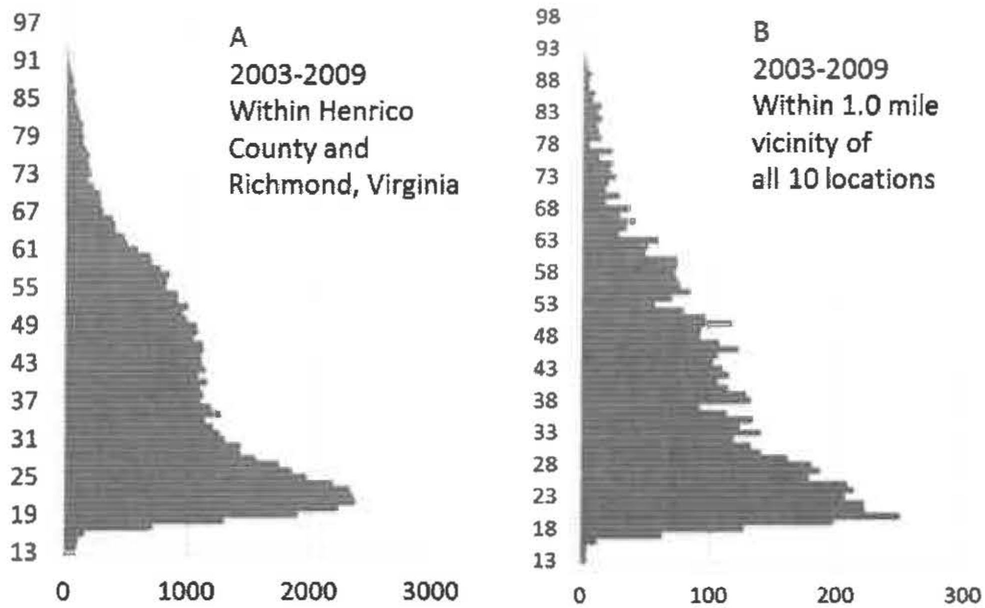


Figure 22. Distributions of Age of Drivers for all Accidents in the Henrico County and Richmond (left, blue), and within 1.0 miles of all Digital Locations (right, purple)

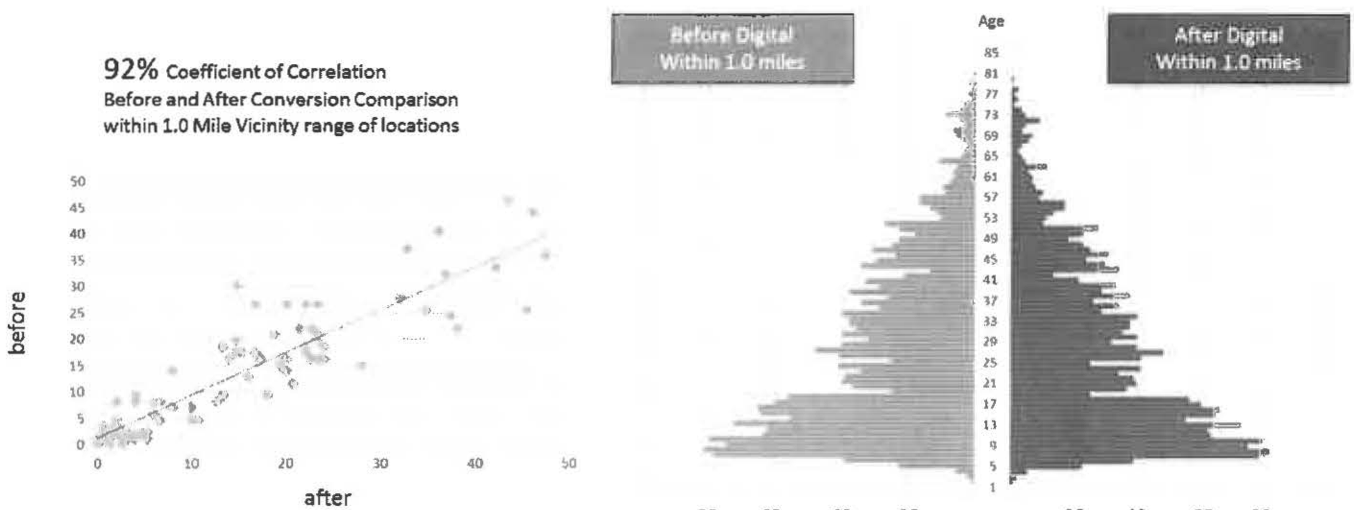


Figure 23. Distributions of Age of Drivers for all Accidents before Digital Conversion (left, orange histogram), after Digital Conversion (right, purple histogram) and the Correlation between Before and After Accident Counts for each Age (left).

COMPARISON OF ACCIDENTS BY TIME OF DAY

The accident statistics are also analyzed to determine if the time of day of the accidents near digital billboards is a factor.

The data are studied to determine if any increases in the accident rates during dawn, daylight, dusk and dark/nighttime conditions occurred. Figure 24 summarizes the accidents and accident-rates by time of day for all accidents within 1.0 miles of the digital locations. The daylight accident rate experienced a 15.5 percent decrease after conversion; the nighttime accident rate experienced a 4.7% decrease.

Figure 25 shows the distributions of times of accidents within 1.0 miles for before conversion (top, blue) and for after conversion (middle, red) data periods of comparison. Figure 25 (bottom) also shows the correlation between before and after conversions for the number of accidents. In comparing the histograms in Figure 25, note the typical distribution type (shape) and typical average values. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for time-of-day factors. Figure 25 shows a 0.90 (90.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Between 2003 and 2009 for equal periods before and after
At 10 locations in Henrico County and Richmond, Virginia
with 10 second duration times

		During Time of Day and Lighting			
		Dawn	Daylight	Dusk	Dark
Prior to Installation	Number of Accidents for equal periods prior to conversion	98	828	124	190
Prior to Installation	Number of Accidents per million vehicles (by hundred thousand AADT)	0.06	0.53	0.08	0.12
As Digital Location	Number of Accidents for equal periods after conversion	66	700	88	181
As Digital Location	Number of Accidents per million vehicles (by hundred thousand AADT)	0.04	0.42	0.05	0.11
Comparison	Change in Number of Accidents	-32	-128	-36	-9
Comparison	Change in Rate per million vehicles (by hundred thousand AADT)	-0.02	-0.11	-0.03	-0.01
Comparison	Percent Change in Number of Accidents	-32.7%	-15.5%	-29.0%	-4.7%
Comparison	Percent Change in Rate of Accidents	-36.2%	-19.9%	-32.8%	-9.8%

Figure 24. Summary of Accident Rates during Dawn, Daylight, Dusk and Dark/Nighttime Conditions within a 0.5 mile vicinity range near ten Digital Billboards Locations with 10-second-duration times in Henrico County and Richmond, Virginia

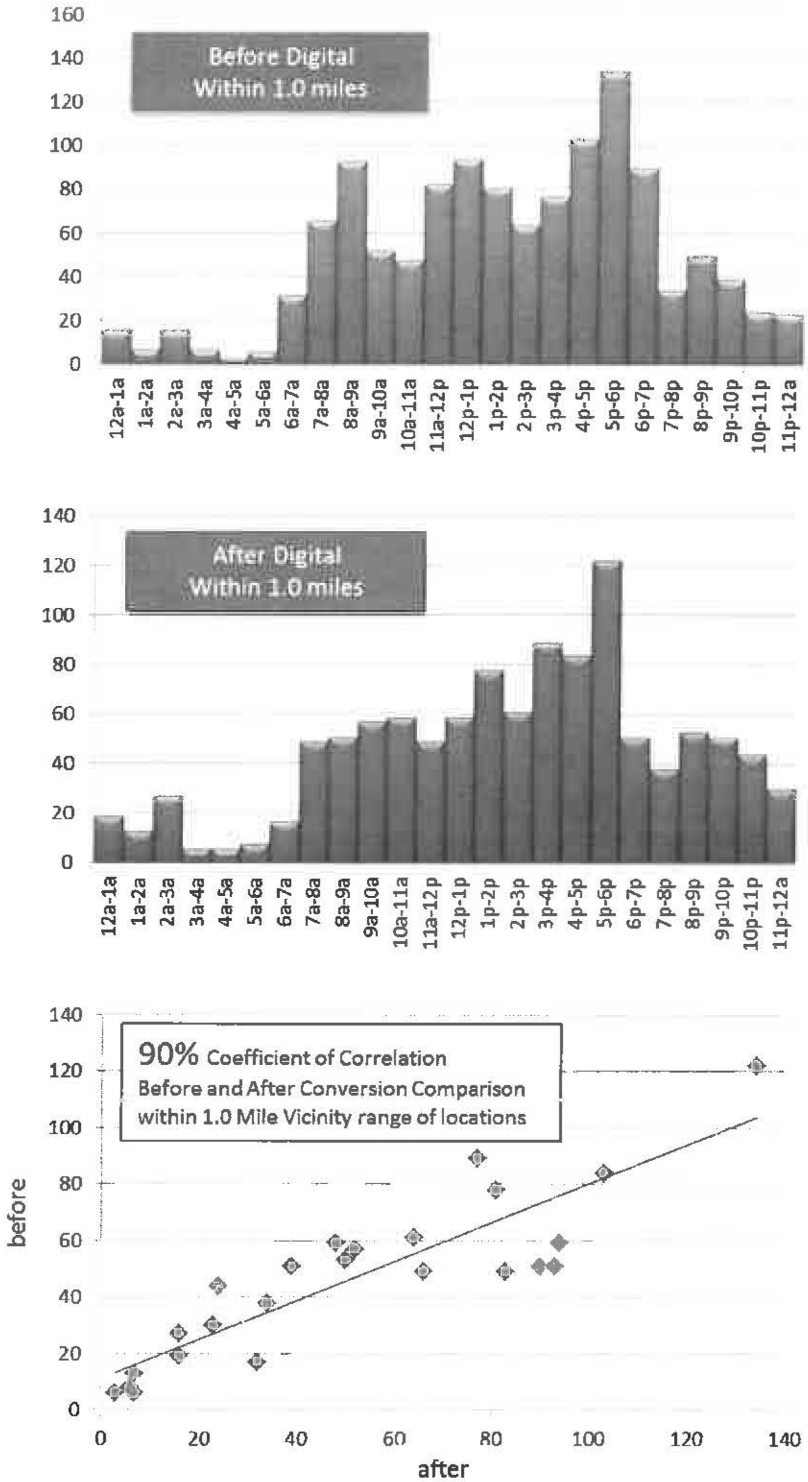


Figure 25. Distributions of Number of Accidents Accident by Time of Day within a 1.0 mile Vicinity Range prior to Digital Conversion (top, blue) and after digital conversion (middle, red) near ten digital billboards locations with 10- second-duration times in Henrico County and Richmond, Virginia

STATISTICAL MODEL AND RESULTS FOR THE EMPIRICAL BAYES METHOD

The Empirical Bayes Method (EBM) is used to analyze available crash data in Henrico County and Richmond, Virginia. The EBM method is a rigorous method capable of estimating the safety impact of changes at a location. The EBM method is well documented and used in numerous traffic-safety studies (see References 14 through 31). Simply stated, the method estimates the number of crashes at a location that would have occurred without the introduction of digital billboards. The estimates may then be compared with the actual crashes that have occurred.

The expected number of crashes as estimated by the Crash Estimation Model (CEM) and using the SAS statistical package and the parameters discussed in our methodology were computed. A multivariate, regression model was developed to estimate the mean of the expected number of crashes at a location. Our general CEM is shown in Figure 26 and models Average Annual Daily Traffic (AADT), Number of Lanes (Lane), and the posted Speed Limit (Speed) as independent variables; $\beta_0, \beta_1, \beta_2$, and β_3 are model parameters of the independent variables. The model is fit using the maximum likelihood method and includes 90 sites representing 10 digital billboard locations and 80 comparison sites. Figure 27 shows these locations. Figure 26 summarizes the CEM parameters using a maximum likelihood estimates for a multivariate regression model with negative binomial distribution. The CEM parameters are significant at $\alpha = 0.05$. The resulting CEM equation is also presented in Figure 26.

The projected, total crash counts were estimated for the "after" periods to represent what the number of crashes would have been in future period without the introduction of digital billboards. These were compared with the crash data that actually occurred after the introduction of digital billboards at each location to determine the overall index of effectiveness.

General CEM: $$P = (AADT)^{\beta_1} (LANE)^{\beta_2} (Speed)^{\beta_3} e^{\beta_0}$$

Explicit CEM: $$P = (AADT)^{.0285} (LANE)^{0.1381} (Speed)^{-0.0070} e^{2.7599}$$

CEM Model Parameters:

Variable		Coefficient	Standard Error	Chi-square statistic	Pr > Chi-square	Wald 90% confidence limits	
						Lower	Upper
Intercept		2.7599	0.1943	201.81	<.0001	2.3792	3.1407
AADT	β_1	0.0285	0.0020	205.35	<.0001	0.0246	0.0324
lanes	β_2	0.1381	0.0293	22.25	<.0001	0.0807	0.1955
speed	β_3	-0.0070	0.0022	10.45	0.0012	-0.0112	-0.0027
Dispersion	ϕ	0.4445	0.0325			0.3808	0.5081

SAS Goodness of fit measures: deviance (value/d.f.) = 438.3687 (1.1014); Pearson chi-square (value/d.f.) = 373.611 (0.9387); Number of observations = 680

Figure 26. General and Explicit Crash Estimation Model (CEM) and CEM Model Parameters from SAS Output

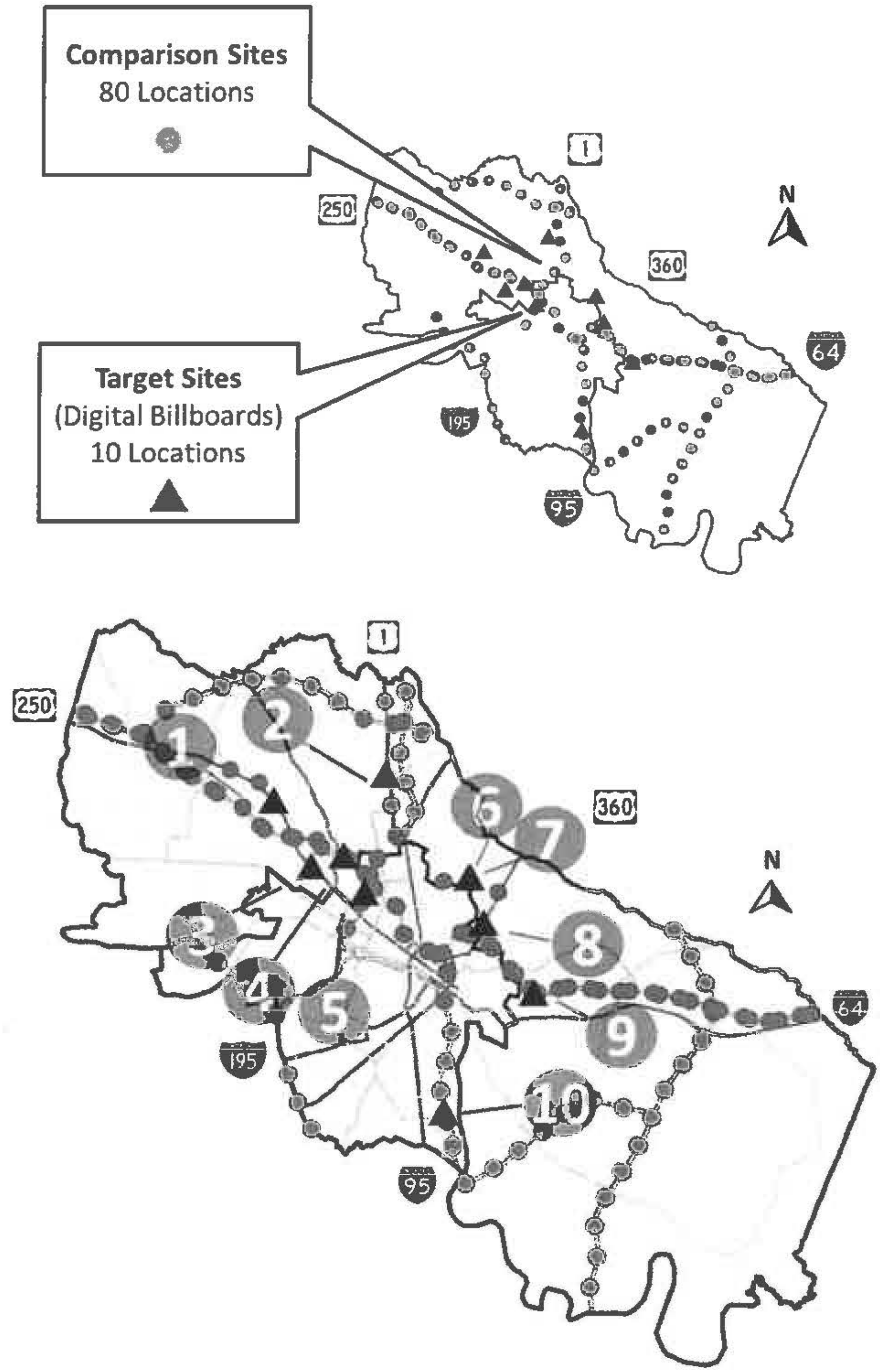


Figure 27. Crash and AADT Data for 10 Target (Digital) Locations and 80 Comparison (non-Digital) Locations

The Empirical Bayes Method results indicate a 0.0142 (1.42%) difference between the "after" conversion crashes that occurred near the 10 digital locations and the statistically predicted Empirical Bayes mean estimate of those same locations had no digital billboards been installed. This comparison has a p-value less than 0.0001. The analysis of this data indicates that the actual and predicted means are almost statistically consistent. A large sample size was used with 10 digital locations, 80 treatment or comparison sites with seven years of accident data. The statistical evaluation of the Empirical Bayes Method analysis shows that the total number of accidents is slightly less than what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 90 locations within Henrico County and Richmond, Virginia. Additional studies should be considered with other independent variables, consider for lower volume roads, other robust crash estimation models, and cross-comparison of results between digital.

Parameter	Value
Total Crashes for the "After" Period with Digital Conversion (Actual Values)	1121
Total Crashes for the "After" Period assuming no Digital Conversion ever occurred (Estimate by Empirical Bayes Method)	1137
Overall Index of Effectiveness	0.986
Percent Change in Crashes between actual and estimate	1.42%

Figure 28. Results of the Empirical Bayes Method Estimation in Henrico County and Richmond, Virginia with 10 digital locations, 80 Treatment or Comparison Sites and with Seven Years of Accident Data

Simply stated, the data show no statistically significant increase of accident rates near these billboards.

FINDINGS

Henrico County and Richmond, Virginia are a unique opportunity for this study about the statistical associations between digital billboards and traffic safety using robust data-sets and analyzing multiple locations for periods of more than seven years. The overall conclusion is that these digital billboards in Richmond have no statistically significant relationship with the occurrence of accidents. This conclusion is based on local Police and VDOT data and an objective statistical analysis; the data show no statistically significant increase in accident rates. This study also finds that **the age of the driver (younger, older)** and **the time of day (nighttime, daytime) are neutral factors** which show no increase in accident rates near these digital billboards along the routes in in Henrico County and Richmond, Virginia.

The specific conclusions of this study indicate the following.

• **The before and after rates of accidents near the 10 digital billboard locations show decreases** within 1.0 miles of all digital billboards for more than seven years. Similar decreases and trends in both averages and peaks are observed for smaller vicinity ranges.

• **The accident statistics and metrics remain consistent**, exhibiting statistically insignificant variations at each of the digital billboards. The metrics include the total number of accidents in any given month, the average number of accidents, the peak number of accidents in any given month, and the number of accident-free months. These conclusions account for variations in traffic-volume and other metrics.

• The statistical evaluation of the Empirical Bayes Method and actual versus predicted results, show that the **total number of accidents is consistent with what would be statistically expected with or without the introduction of digital technology** and that the safety near this locations are consistent with the model benchmarked by 90 locations within and near Richmond Virginia.

• The overall conclusion of the study is that **these digital billboards in Richmond have no statistically significant relationship with the occurrence of accidents**.

This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. These conclusions are based on the collected Police Department data and on an objective statistical analysis.

REFERENCES

1. Traffic Volumes, prepared by the Virginia Department of Transportation, in Association with U.S. Department of Transportation, Federal Highway Administration, various years.
2. Virginia Traffic Crash Information Reports by the Virginia Department of Transportation, Traffic Safety Bureau and produced by the Division of Government Research, various years.
3. Tantala, M., P. Tantala, "An Examination of the Relationship between Advertising Signs and Traffic Safety", 84th Transportation Research Board (TRB) Annual Conference Proceedings, Washington, D.C., 2005.
4. Tantala, M., A. Tantala, "A Study of the Relationship between Digital Billboards and Traffic Safety in Cuyahoga County, Ohio", 2007.
5. GIS BaseMap: planning level set of data, Virginia Department of Transportation.
6. Tantala, Site Observation Notes, Photos, Digital Videos, and geospatial log files, 2010
7. Traffic Count Reports, various locations, various dates, 2001-2009.
8. Ang, A., W. Tang, Probability Concepts in Engineering Planning and Design, John Wiley and Sons, Inc., 1975.
9. Garber, N. and L. Hoel, Traffic and Highway Engineering, PWS Publishing, 2nd edition (Revised Printing), 1999.
10. Harr, M., Reliability Based Design in Civil Engineering, General Publishing Company, Ltd., 1987.
11. National Oceanic & Atmospheric Administration (NOAA), U.S. Department of Commerce, Historical Weather Data for Virginia, 2003-2009.
12. Federal Highway Administration. Manual on Uniform Traffic Control Devices (MUTCD), Washington, D.C.: Federal Highway Administration, 2003.
13. American National Standards Institute (ANSI D16.1), Manual on Classification of Motor Vehicle Accidents, 1996.
14. American Association of State Highway and Transportation Officials (AASHTO), Highway Safety Manual (HSM-1), First Edition, 2010.
15. Eustace, D., "Analyzing the Effects of LED Traffic Signals on Urban Intersection Safety", ITE Journal, April 2010.
16. Hauer, E., "Observational Before-After Studies in Road Safety", 2nd Ed. Elsevier Science Ltd., 2002.
17. Hauer, E., et al., "Estimating Safety by the Empirical Bayes Method: A Tutorial", Transportation Research Record, Vol. 1784, 2002.
18. Persaud, B., et al., "Safety Effect of Roundabout Conversions in the United States: Empirical Bayes Observational Before-After Study", Transportation Research Record, Vol. 1751, 2001.

19. Hirst, W., et al., "Sources of Error in Road Scheme Evaluation: A Quantified Comparison of Current Methods", Accident Analysis & Prevention, Vol. 36, No. 5, 2004.

20. Garber, N., et al., "The Safety Impacts of Differential Speed Limits on Rural Interstate Highways", Report No. FHWA-HRT-05-042, Federal Highway Administration, Washington, D.C., 2005.

21. Hovey, P. and M. Chowdhury, "Development of Crash Reduction Factors", Final Report. Ohio Department of Transportation, Columbus, Ohio, 2005.

22. Ossenbruggen, P. and E. Linder, "Hazardous Roadway Identification Using Bayesian Data Analysis", TRB 2006 Annual Meeting CDROM, Transportation Research Board, Washington, D.C., 2006.

23. Miller, J., et al., "Safety Impacts of Photo-Red Enforcement at Suburban Signalized Intersections: An Empirical Bayes Approach", Transportation Research Record, No. 1969, 2006.

24. Persaud, B. and C. Lyon. "Empirical Bayes Before-and-After Studies: Lessons Learned from Two Decades of Experience", TRB 2006 Annual Meeting CD-ROM, Transportation Research Board, Washington, D.C., 2006.

25. Angelastro, M., "The Influence of Driver Sight Distance on Crash Rates and Driver Speed at Modern Roundabouts in the United States", ITE Journal, July 2010.

26. Powers, M. and J. Carson, "Before-After Crash Analysis: A Primer for Using the Empirical Bayes Method", Prepared for Montana Department of Transportation, May 2004.

27. Hovey, P. and M. Chowdhury, "Development of Crash Reduction Factors", Prepared for Ohio Department of Transportation, September 2005.

28. Chatterjee, A., et al., "Planning Level Regression Models for Crash Prediction on Interchange and Non-Interchange Segments of Urban Freeways", Prepared for the Southeastern Transportation Center, University of Tennessee, 2005.

29. Donnell, E. and J. Mason Jr., "Predicting the Frequency of Median Barrier Crashes on Virginia Interstate Highways", Elsevier Science Ltd., 2005.

30. Chen, L., et al., "Confirmatory and Exploratory Data Analysis Using PROC GENMOD: Factors Associated with Red Light Running Crashes", Northeast SAS Users Group 13th Annual Conference Proceedings, 2000.

31. Persaud, B. and C. Lyon, "Evaluation of Lane Reduction "Road Diet" Measures on Crashes", NCHRP Report 617: Accidental Modification Factors for Traffic Engineering and ITS Improvements, Transportation Research Board, Washington, D.C., 2008.

TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
www.TANTALA.com

Topic:	Drivers Visual Behavior in the Presence of CEVMS
Date Submitted:	September 18, 2017
Submitted By:	Michael Ruthsatz
Venue:	Natural Resources Committee

DRIVER VISUAL BEHAVIOR IN THE PRESENCE OF COMMERCIAL ELECTRONIC VARIABLE MESSAGE SIGNS (CEVMS)

SEPTEMBER 2012

U.S. Department of Transportation
Federal Highway Administration

FHWA-HEP-

Topic: Drivers Visual Behavior in the Presence of CEVMS
Date Submitted: September 18, 2017
Submitted By: Michael Ruthsatz
Venue: Natural Resources Committee

FOREWORD

The advent of electronic billboard technologies, in particular the digital Light-Emitting Diode (LED) billboard, has necessitated a reevaluation of current legislation and regulation for controlling outdoor advertising. In this case, one of the concerns is possible driver distraction. In the context of the present report, outdoor advertising signs employing this new advertising technology are referred to as Commercial Electronic Variable Message Signs (CEVMS). They are also commonly referred to as Digital Billboards and Electronic Billboards.

The present report documents the results of a study conducted to investigate the effects of CEVMS used for outdoor advertising on driver visual behavior in a roadway driving environment. The report consists of a brief review of the relevant published literature related to billboards and visual distraction, the rationale for the Federal Highway Administration research study, the methods by which the study was conducted, and the results of the study, which used an eye tracking system to measure driver glances while driving on roadways in the presence of CEVMS, standard billboards, and other roadside elements. The report should be of interest to highway engineers, traffic engineers, highway safety specialists, the outdoor advertising industry, environmental advocates, Federal policymakers, and State and local regulators of outdoor advertising.

Monique R. Evans
Director, Office of Safety
Research and Development

Nelson Castellanos
Director, Office of Real Estate
Services

TECHNICAL DOCUMENTATION PAGE

1. Report No. FHWA-HRT-	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS)	5. Report Date 6. Performing Organization Code
7. Author(s) William A. Perez, Mary Anne Bertola, Jason F. Kennedy, and John A. Molino	8. Performing Organization Report No.
9. Performing Organization Name and Address SAIC 6300 Georgetown Pike McLean, VA 22101	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Real Estate Services Federal Highway Administration 1200 New Jersey Avenue SE Washington, DC 20590	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes
The Contracting Officer's Technical Representatives (COTR) were Christopher Monk and Thomas Granda.

16. Abstract
This study was conducted to investigate the effect of CEVMS on driver visual behavior in a roadway driving environment. An instrumented vehicle with an eye tracking system was used. Roads containing CEVMS, standard billboards, and control areas with no off-premise advertising were selected. Data were collected on arterials and freeways in the day and nighttime. Field studies were conducted in two cities where the same methodology was used but there were differences in the roadway visual environment. The gazes to the road ahead were high across the conditions; however, the CEVMS and billboard conditions resulted in a lower probability of gazes as compared to the control conditions (roadways not containing off-premise advertising) with the exception of arterials in Richmond where none of the conditions differed from each other. Examination of where drivers gazed in the CEVMS and standard billboard conditions showed that gazes away from the road ahead were not primarily to the billboards. Average and maximum fixations to CEVMS and standard billboards were similar across all conditions. However, four long dwell times were found (sequential and multiple fixations) that were greater than 2,000 ms. One was to a CEVMS on a freeway in the day time, two were to the same standard billboard on a freeway once in the day and once at night; and one was to a standard billboard on an arterial at night. In Richmond, the results showed that drivers gazed more at CEVMS than at standard billboards at night; however, in Reading the drivers were equally likely to gaze towards CEVMS or standard billboards in day and night. The results of the study are consistent with research and theory on the control of gaze behavior in natural environments. The demands of the driving task tend to affect the driver's self-regulation of gaze behavior.

17. Key Words Driver visual behavior, visual environment, billboards, eye tracking system, commercial electronic variable message signs, CEVMS, visual complexity	18. Distribution Statement No restrictions.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND SYMBOLS

CEVMS	Commercial Electronic Variable Message Sign
EB	Empirical Bayes
DCZ	Data Collection Zone
ROI	Region of Interest
LED	Light-Emitting Diode
IR	Infra-Red
CCD	Charge-Coupled Device
MAPPS	Multiple-Analysis of Psychophysical and Performance Signals
GEE	Generalized Estimating Equations
FHWA	Federal Highway Administration
DOT	Department of Transportation

EXECUTIVE SUMMARY

This study examines where drivers look when driving past commercial electronic variable message signs (CEVMS), standard billboards, or no off-premise advertising. The results and conclusions are presented in response to the three research questions listed below:

1. Do CEVMS attract drivers' attention away from the forward roadway and other driving-relevant stimuli?

2. Do glances to CEVMS occur that would suggest a decrease in safety?

3. Do drivers look at CEVMS more than at standard billboards?

This study follows a Federal Highway Administration (FHWA) review of the literature on the possible distracting and safety effects of off-premise advertising and CEVMS in particular. The review considered laboratory studies, driving simulator studies, field research vehicle studies, and crash studies. The published literature indicated that there was no consistent evidence showing a safety or distraction effect due to off-premise advertising. However, the review also enumerated potential limitations in the previous research that may have resulted in the finding of no distraction effects for off-premise advertising. The study team recommended that additional research be conducted using instrumented vehicle research methods with eye tracking technology.

The eyes are constantly moving and they fixate (focus on a specific object or area), perform saccades (eye movements to change the point of fixation), and engage in pursuit movements (track moving objects). It is during fixations that we take in detailed information about the environment. Eye tracking allows one to determine to what degree off-premise advertising may divert attention away from the forward roadway. A finding that areas containing CEVMS result in significantly more gazes to the billboards at a cost of not gazing toward the forward roadway would suggest a potential safety risk. In addition to measuring the degree to which CEVMS may distract from the forward roadway, an eye tracking device would allow an examination of the duration of fixations and dwell times (multiple sequential fixations) to CEVMS and standard billboards. Previous research conducted by the National Highway Traffic Safety Administration (NHTSA) led to the conclusion that taking your eyes off the road for 2 seconds or more presents a safety risk. Measuring fixations and dwell times to CEVMS and standard billboards would also allow a determination as to the degree to which these advertising signs lead to potentially unsafe gaze behavior.

Most of the literature concerning eye gaze behavior in dynamic environments suggests that task demands tend to override visual salience (an object that stands out because of its physical properties) in determining attention allocation. When extended to driving, it would be expected that visual attention will be directed toward task-relevant areas and objects (e.g., the roadway, other vehicles, speed limit signs) and that other salient objects, such as billboards, would not necessarily capture attention. However, driving is a somewhat automatic process and conditions generally do not require constant, undivided attention. As a result, salient stimuli, such as CEVMS, might capture driver attention and produce an unwanted increase in driver distraction. The present study addresses this concern.

This study used an instrumented vehicle with an eye tracking system to measure where drivers were looking when driving past CEVMS and standard billboards. The CEVMS and standard billboards were measured with respect to luminance, location, size, and other relevant variables to characterize these visual stimuli extensively. Unlike previous studies on digital billboards, the present study examined CEVMS as deployed in two United States cities. These billboards did not contain dynamic video or other dynamic elements, but changed content approximately every 8 to 10 seconds. The eye tracking system had nearly a 2-degree level of resolution that provided significantly more accuracy in determining what objects the drivers were looking at compared to an earlier naturalistic driving study. This study assessed two data collection efforts that employed the same methodology in two cities.

In each city, the study examined eye glance behavior to four CEVMS, two on arterials and two on freeways. There were an equal number of signs on the left and right side of the road for arterials and freeways. The standard billboards were selected for comparison with CEVMS such that one standard billboard environment matched as closely as possible that of each of the CEVMS. Two control locations were selected that did not contain off-premise advertising, one on an arterial and the other on a freeway. This resulted in 10 data collection zones in each city that were approximately 1,000 feet in length (the distance from the start of the data collection zone to the point that the CEVMS or standard billboard disappeared from the data collection video).

In Reading, Pennsylvania, 14 participants drove at night and 17 drove during the day. In Richmond, Virginia, 10 participants drove at night and 14 drove during the day. Calibration of the eye tracking system, practice drive, and the data collection drive took approximately 2 hours per participant to accomplish.

The following is a summary of the study results and conclusions presented in reference to the three research questions the study aimed to address.

Do CEVMS attract drivers' attention away from the forward roadway and other driving relevant stimuli?

- On average, the drivers in this study devoted between 73 and 85 percent of their visual attention to the road ahead for both CEVMS and standard billboards. This range is consistent with earlier field research studies. In the present study, the presence of CEVMS did not appear to be related to a decrease in looking toward the road ahead.

Do glances to CEVMS occur that would suggest a decrease in safety?

- The average fixation duration to CEVMS was 379 ms and to standard billboards it was 335 ms across the two cities. The average fixation durations to CEVMS and standard billboards were similar to the average fixation duration to the road ahead.
- The longest fixation to a CEVMS was 1,335 ms and to a standard billboard it was 1,284 ms. The current widely accepted threshold for durations of glances away from the road ahead that result in higher crash risk is 2,000 ms. This value comes from a NHTSA

naturalistic driving study that showed a significant increase in crash odds when glances away from the road ahead were 2,000 ms or longer.

- Four dwell times (aggregate of consecutive fixations to the same object) greater than 2,000 ms were observed across the two studies. Three were to standard billboards and one was to a CEVMS. The long dwell time to the CEVMS occurred in the daytime to a billboard viewable from a freeway. Review of the video data for these four long dwell times showed that the signs were not far from the forward view while participant's gaze dwelled on them. Therefore, the drivers still had access to information about what was in front of them through peripheral vision.

- The results did not provide evidence indicating that CEVMS, as deployed and tested in the two selected cities, were associated with unacceptably long glances away from the road. When dwell times longer than the currently accepted threshold of 2,000 ms occurred, the road ahead was still in the driver's field of view. This was the case for both CEVMS and standard billboards.

Do drivers look at CEVMS more than at standard billboards?

- When comparing the probability of a gaze at a CEVMS versus a standard billboard, the drivers in this study were generally more likely to gaze at CEVMS than at standard billboards. However, some variability occurred between the two locations and between the types of roadway (arterial or freeway).

- In Reading, when considering the proportion of time spent looking at billboards, the participants looked more often at CEVMS than at standard billboards when on arterials (63 percent to CEVMS and 37 percent to a standard billboard), whereas they looked more often at standard billboards when on freeways (33 percent to CEVMS and 67 percent to a standard billboard). In Richmond, the drivers looked at CEVMS more than standard billboards no matter the type of road they were on, but as in Reading, the preference for gazing at CEVMS was greater on arterials (68 percent to CEVMS and 32 percent to standard billboards) than on freeways (55 percent to CEVMS and 45 percent to standard billboards). When a gaze was to an off-premise advertising sign, the drivers were generally more likely to gaze at a CEVMS than at a standard billboard.

- In Richmond, the drivers showed a preference for gazing at CEVMS versus standard billboards at night, but in Reading the time of day did not affect gaze behavior. In Richmond, drivers gazed at CEVMS 71 percent and at standard billboards 29 percent at night. On the other hand, in the day the drivers gazed at CEVMS 52 percent and at standard billboards 48 percent.

- In Reading, the average gaze dwell time for CEVMS was 981 ms and for standard billboards it was 1,386 ms. The difference in these average dwell times was not statistically significant. In contrast, the average dwell times to CEVMS and standard billboards were significantly different in Richmond (1,096 ms and 674 ms, respectively).

The present data suggest that the drivers in this study directed the majority of their visual attention to areas of the roadway that were relevant to the task at hand (e.g., the driving task). Furthermore, it is possible, and likely, that in the time that the drivers looked away from the forward roadway, they may have elected to glance at other objects in the surrounding environment (in the absence of billboards) that were not relevant to the driving task. When billboards were present, the drivers in this study sometimes looked at them, but not such that overall attention to the forward roadway decreased.

It also should be noted that, like other studies in the available literature, this study adds to the knowledge base on the issues examined, but does not present definitive answers to the research questions investigated.

INTRODUCTION

"The primary responsibility of the driver is to operate a motor vehicle safely. The task of driving requires full attention and focus. Drivers should resist engaging in any activity that takes their eyes and attention off of the road for more than a couple of seconds. In some circumstances even a second or two can make all the difference in a driver being able to avoid a crash." – US Department of Transportation[1]

The advent of electronic billboard technologies, in particular the digital Light-Emitting Diode (LED) billboard, has prompted a reevaluation of regulations for controlling outdoor advertising. An attractive quality of these LED billboards, which are hereafter referred to as Commercial Electronic Variable Message Signs (CEVMS), is that advertisements can change almost instantly. Furthermore, outdoor advertising companies can make these changes from a central remote office. Of concern is whether or not CEVMS may attract drivers' attention away from the primary task (driving) in a way that compromises safety.

The current Federal Highway Administration (FHWA) guidance recommends that CEVMS should not change content more frequently than once every 8 seconds.[2] However, according to Scenic America, the basis of the safety concern is that the "...distinguishing trait..." of a CEVMS "... is that it can vary while a driver watches it, in a setting in which that variation is likely to attract the drivers' attention away from the roadway."[3]This study was conducted to provide the FHWA with data to determine if CEVMS capture visual attention differently than standard off-premise advertising billboards.

BACKGROUND

A 2009 review of the literature by Molino et al. for the FHWA failed to find convincing empirical evidence that CEVMS, as currently implemented, constitutes a safety risk greater than that of conventional vinyl billboards.[4] A great deal of work has been focused in this area, but the findings of these studies have been mixed.[4,5] A summary of the key past findings is presented here, but the reader is referred to Molino et al. for a comprehensive review of studies prior to 2008.[4]

Post-Hoc Crash Studies

Post-hoc crash studies use reviews of police traffic collision reports or statistical summaries of such reports in an effort to understand the causes of crashes that have taken place in the vicinity of some change to the roadside environment. In the present case, the change of concern is the introduction of CEVMS to the roadside or the replacement of conventional billboards with CEVMS.

The literature review conducted by Molino et al. did not find compelling evidence for a distraction effect attributable to CEVMS.[4] The authors concluded that all post-hoc crash studies are subject to certain weaknesses, most of which are difficult to overcome. For example, the vast majority of crashes are never reported to police; thus, such studies are likely to underreport crashes. Also, when crashes are caused by factors such as driver distraction or inattention, the involved driver may be unwilling or unable to report these factors to a police investigator.

Another weakness is that police, under time pressure, are rarely able to investigate the true root causes of crashes unless they involve serious injury, death, or extensive property damage. Furthermore, to have confidence in the results, such studies need to collect comparable data before and after the change, and, in the after phase, at equivalent but unaffected roadway sections. Since crashes are infrequent events, data collection needs to span extended periods of time both before and after introduction of the change. Few studies are able to obtain such extensive data.

Two recent studies by Tantala and Tantala examined the relationship between the presence of CEVMS and crash statistics in Richmond, Virginia, and Reading, Pennsylvania.[6,7] For the Richmond area, 7 years of crash data at 10 locations with CEVMS were included in the analyses. The study used a before-after methodology where most sites originally contained vinyl billboards (before) that were converted to CEVMS (after). The quantity of crash data was not the same for all locations and ranged from 1 year before/after to 3 years before/after. The study employed the Empirical Bayes (EB) method to analyze the data.[8] The results indicated that the total number of crashes observed was consistent with what would be statistically expected with or without the introduction of CEVMS. The analysis approach for Reading locations was much the same as for Richmond other than there were 20 rather than 10 CEVMS and 8 years of crash statistics. The EB method showed results for Reading that were very similar to those of Richmond.

The studies by Tantala and Tantala appear to address many of the concerns from Molino et al. regarding the weaknesses and issues associated with crash studies.[4,6,7] For example, they include crash comparisons for locations within multiple distances of each CEVMS to address concerns about the visual range used in previous analyses. They used EB analysis techniques to correct for regression-to-mean bias. Also, the EB method would better reflect crash rate changes due to changes in average daily traffic and the interactions of these with the roadway features that were coded in the model. The studies followed approaches that are commonly used in post-hoc crash studies, though the results would have been strengthened by including before-after results for non-CEVMS locations as a control group.

Field Investigations

Field investigations include unobtrusive observation, naturalistic driving studies, on-road instrumented vehicle investigations, test track experiments, driver interviews, surveys, and questionnaires. The following focuses on relevant studies that employed naturalistic driving and on-road instrumented vehicle research methods.

Lee, McElheny, and Gibbons undertook an on-road instrumented vehicle study on Interstate and local roads near Cleveland, Ohio.[9] The study looked at driver glance behavior in the vicinity of digital billboards, conventional billboards, comparison sites (sites with buildings and other signs, including digital signs), and control sites (those without similar signage). The results showed that there were no differences in the overall glance patterns (percent eyes-on-road and overall number of glances) between the different sites. Drivers also did not glance more frequently in the direction of digital billboards than in the direction of other event types (conventional billboards, comparison events, and baseline events) but drivers did take longer glances in the direction of digital billboards and comparison sites than in the direction of conventional billboards and baseline sites. However, the mean glance length toward the digital billboards was less than

1,000 ms. It is important to note that this study employed a video-based approach for examining drivers' visual behavior, which has an accuracy of no better than 20 degrees.[10] While this technique is likely to be effective in assessing gross eye movements and looks that are away from the road ahead, it may not have sufficient resolution to discriminate what specific object the driver is looking at outside of the vehicle.

Beijer, Smiley, and Eizenman evaluated driver glances toward four different types of roadside advertising signs on roads in the Toronto, Canada, area.[11] The four types of signs were: (a) billboard signs with static advertisements; (b) billboard advertisements placed on vertical rollers that could rotate to show one of three advertisements in succession; (c) scrolling text signs with a minor active component, which usually consisted of a small strip of lights that formed words scrolling across the screen or, in some cases, a larger area capable of displaying text but not video; and (d) signs with video images that had a color screen capable of displaying both moving text and moving images. The study employed an on-road instrumented vehicle with a head-mounted eye tracking device. The researchers found no significant differences in average glance duration or the maximum glance duration for the various sign types; however, the number of glances was significantly lower for billboard signs than for the roller bar, scrolling text, and video signs.

Smiley, Smahel, and Eizenman conducted a field driving study that employed an eye tracking system that recorded drivers' eye movements as participants drove past video signs located at three downtown intersections and along an urban expressway.[12] The study route included static billboards and video advertising. The results of the study showed that on average 76 percent of glances were to the road ahead. Glances at advertising, including static billboards and video signs, constituted 1.2 percent of total glances. The mean glance durations for advertising signs were between 500 ms and 750 ms, although there were a few glances of about 1,400 ms in duration. Video signs were not more likely than static commercial signs to be looked at when headways were short; in fact, the reverse was the case. Furthermore, the number of glances per individual video sign was small, and statistically significant differences in looking behavior were not found.

Kettwich, Kartsen, Klinger, and Lemmer conducted a field study where drivers' gaze behavior was measured with an eye tracking system.[13] Sixteen participants drove an 11.5 mile (18.5 km) route comprised of highways, arterial roads, main roads, and one-way streets in Karlsruhe, Germany. The route contained advertising pillars, event posters, company logos, and video screens. Mean gaze duration for the four types of advertising was computed for periods when the vehicle was in motion and when it was stopped. Gaze duration while driving for all types of advertisements was under 1,000 ms. On the other hand, while the vehicle was stopped, the mean gaze duration for video screen advertisements was 2,750 ms. The study showed a significant difference between gaze duration while driving and while stationary: gaze duration was affected by the task at hand. That is, drivers tended to gaze longer while the car was stopped and there were few driving task demands.

The previously mentioned studies estimated the duration of glances to advertising and computed mean values of less than 1,000 ms. Klauer et al., in his analysis of the 100-Car Naturalistic Driving Study, concluded that glances away from the roadway for any purpose lasting more than 2,000 ms increase near-crash/crash risk by at least two times that of normal, baseline driving.[14]

Klauer et al. also indicated that short, brief glances away from the forward roadway for the purpose of scanning the driving environment are safe and actually decrease near-crash/crash risk.[14] Using devices in a vehicle that draw visual attention away from the forward roadway for more than 2,000 ms (e.g., texting) is incompatible with safe driving. However, for external stimuli, especially those near the roadway, the evaluation of eye glances with respect to safety is less clear since peripheral vision would allow the driver to still have visual access to the forward roadway.

Laboratory Studies

Laboratory investigations related to roadway safety can be classified into several categories: driving simulations, non-driving-simulator laboratory testing, and focus groups. The review of relevant laboratory studies by Molino et al. did not show conclusive evidence regarding the distracting effects of CEVMS.[4] Moreover, the authors concluded that present driving simulators do not have sufficient visual dynamic range, image resolution, and contrast ratio capability to produce the compelling visual effect of a bright, photo-realistic LED-based CEVMS against a natural background scene. The following is a discussion of a driving simulator study conducted after the publication of Molino et al.[4] The study focused on the effects of advertising on driver visual behavior.

Chattington, Reed, Basacik, Flint, and Parkes conducted a driving simulator study in the United Kingdom (UK) to evaluate the effects of static and video advertising on driver glance behavior.[15] The researchers examined the effects of advertisement position relative to the road (left, right, center on an overhead gantry, and in all three locations simultaneously), type of advertisement (static or video), and exposure duration of the advertisement. (The paper does not provide these durations in terms of time or distance. The exposure duration had to do with the amount of time or distance that the sign would be visible to the driver.) For the advertisements presented on the left side of the road (recall that drivers travel in the left lane in the UK), mean glance durations for static and video advertisements were significantly longer (approximately 650 to 750 ms) when drivers experienced long advertisement exposure as opposed to medium and short exposures. Drivers looked more at video advertisements (about 2 percent on average of the total duration recorded) than at static advertisements (about 0.75 percent on average). In addition, the location of the advertisements had an effect on glance behavior. When advertisements were located in the center of the road or in all three positions simultaneously, the glance durations were about 1,000 ms and were significantly longer than for signs placed on the right or left side of the road. For advertisements placed on the left side of the road, there was a significant difference in glance duration between static (about 400 ms) and video (about 800 ms). Advertisement position also had an effect on the proportion of time that a driver spent looking at an advertisement. The percentage of time looking at advertisements was greatest when signs were placed in all three locations, followed by center location signs, then the left location signs, and finally the right location signs. Drivers looked more at the video advertisements relative to the static advertisements when they were placed in all three locations, placed on the left, and placed on the right side of the road. The center placement did not show a significant difference in percent of time spent looking between static and video.

Summary

The results from these key studies offer some insight into whether CEVMS pose a visual distraction threat. However, these same studies also reveal some inconsistent findings and potential methodological issues that are addressed in the current study. The studies conducted by Smiley et al. showed drivers glanced forward at the roadway about 76 percent of the time in the presence of video and dynamic signs where a few long glances of approximately 1,400 ms were observed.[12] However, the video and dynamic signs used in these studies portray moving objects that are not present in CEVMS as deployed in the United States. In another field study employing eye tracking, Kettwich et al. found that gaze duration while driving for all types of advertisements that they evaluated was less than 1,000 ms; however, when the vehicle was stopped, mean gaze duration for advertising was as high as 2,750 ms.[16] Collectively, these studies did not demonstrate that the advertising signs detracted from drivers' glances forward at the roadway in a substantive manner while the vehicle was moving.

In contrast, the simulator study by Chattington et al. demonstrated that dynamic signs showing moving video or other dynamic elements may draw attention away from the roadway.[15] Furthermore, the location of the advertising sign on the road is an important factor in drawing drivers' visual attention. Advertisements with moving video placed in the center of the roadway on an overhead gantry or in all three positions (right, left, and in the center) simultaneously are very likely to draw glances from drivers.

Finally, in a study that examined CEVMS as deployed in the United States, Lee et al. did not show any significant effects of CEVMS on driver glance behavior.[9] However, the methodology that was used likely did not employ sufficient sensitivity to determine at what specific object in the environment a driver was looking.

None of these studies combined all necessary factors to address the current CEVMS situation in the United States. Those studies that used eye tracking on real roads had animated and video-based signs, which are not reflective of current off-premise CEVMS practice in the United States.

STUDY APPROACH

Based on an extensive review of the literature, Molino et al. concluded that the most effective method to use in an evaluation of the effects of CEVMS on driver visual behavior was the instrumented field vehicle method that incorporated an eye tracking system.[4] The present study employed such an instrumented field vehicle with an eye tracking system and examined the degree to which CEVMS attract drivers' attention away from the forward roadway.

The following presents a brief overview and discussion of studies using eye tracking methodology with complex visual stimuli, especially in natural environments (walking, driving, etc.). The review by Molino et al. recommended the use of this type of technology and method; however, a discussion laying out technical and theoretical issues underlying the use of eye tracking methods was not presented.[4] This background is important for the interpretation of the results of the studies conducted here.

Standard and digital billboards are often salient stimuli in the driving environment, which may make them conspicuous. Cole and Hughes define attention conspicuity as the extent to which a stimulus is sufficiently prominent in the driving environment to capture attention. Further, Cole and Hughes state that attention conspicuity is a function of size, color, brightness, contrast relative to surroundings, and dynamic components such as movement and change.(17) It is clear that under certain circumstances image salience or conspicuity can provide a good explanation of how humans orient their attention.

At any given moment a large number of stimuli reach our senses, but only a limited number of them are selected for further processing. In general, attention can be focused on a stimulus because it is important for achieving some goal, or because the properties of the stimulus can attract the attention of the observer independent of their intentions (e.g., a car horn may elicit an orienting response). When the focus of attention is goal directed, it is referred to as top-down. When the focus of attention is principally a function of stimulus attributes, it is referred to as bottom-up.(18)

In general, billboards (either standard or CEVMS) are not relevant to the driving task but are presumably designed to be salient stimuli in the environment where they may draw a driver's attention. The question is to what degree CEVMS draw a driver's attention away from driving-relevant stimuli (e.g., road ahead, mirrors, and speedometer) and is this different from a standard billboard? In his review of the literature Wachtel leads one to consider CEVMS as stimuli in the environment where attention to them would be drawn in a bottom-up manner; that is, the salience of the billboards would make them stand out relative to other stimuli in the environment and drivers would reflexively look at these signs.(19) Wachtel's conclusions were in reference to research by Theeuwees who employed simple letter stimulus arrays in a laboratory task.(20) Research using simple visual stimuli in a laboratory environment are very useful for testing different theories of perception, but often lack direct application to tasks such as driving. The following discusses research using complex visual stimuli and tasks that are more relevant to natural vision as experienced in the driving task.

A recent review of stimulus salience and eye guidance by Tatler et al. shows that most of the evidence for the capture of attention by the conspicuity of stimuli comes from research in which the stimulus is a simple visual search array or in which the target is uniquely defined by simple visual features.(21) In other words, these are laboratory studies that use letters, arrays of letters, or simple geometric patterns as the stimuli. Pure salience-based models are capable of predicting eye movement endpoint in simple displays, but are less successful for more complex scenes that contain task-relevant and task-irrelevant salient areas.(22,23)

Research by Henderson et al. using photographs of actual scenes showed that subjects looked at non-salient scene regions containing a search target and rarely looked at salient non-task-relevant regions of the scenes.(24) Salience of the stimulus alone was not a good predictor of where participants looked. Additional research by Henderson using photographs of real world scenes also showed that subjects fixated on regions of the pictures that provided task-relevant information rather than visually salient regions with no task-relevant information. However, Henderson acknowledges that static pictures have many shortcomings when used as surrogates for real environments.(25)

Land's review of eye movements in dynamic environments concluded that the eyes are proactive and typically seek out information required in the second before each new activity commences.(26) Specific tasks (e.g., driving) have characteristic but flexible patterns of eye movement that accompany them, and these patterns are similar between individuals. Land concluded that the eyes rarely visit objects that are irrelevant to the task, and the conspicuity of objects is less important than the objects' roles in the task. In a subsequent review of eye movement and natural behavior, Land concluded that in a task that requires fixation on a sequence of specific objects, the capture of gaze by irrelevant salient objects would, in general, be an obtrusive nuisance.(22)

The literature examining gaze control under natural behavior suggests that it is principally top-down driven, or intentional.(24,25,26,22,21,27) However, top-down processing does not explain all gaze control or eye movements. For example, imagine driving down a two-lane country road and a deer jumps into the road. It is most likely that you will attend and react to this deer. Unplanned or unexpected stimuli capture our attention as we engage in complex natural tasks. Research by Jovancevic-Misic and Hayhoe showed that human gaze patterns are sensitive to the probabilistic nature of the environment.(28) In this study, participants' eye movement behavior was observed while walking among other pedestrians. The other pedestrians were confederates and were either safe, risky, or rogue pedestrians. When the study began, the risky pedestrian took a collision course with the participant 50 percent of the time, and the rogue pedestrian always assumed a collision course as he approached the participant, whereas the safe pedestrian never took a collision course. Midway through the study the rogue and safe pedestrians exchanged roles but the risky pedestrian role remained the same. The participants were not informed about the behavior of the other pedestrians. Participants were asked to follow a circular path for several laps and to avoid other pedestrians. The study showed that the participants modified their gaze behavior in response to the change in the other pedestrians' behavior. Jovancevic-Misic concluded that participants learned new priorities for gaze allocation within a few encounters and looked both sooner and longer at potentially dangerous pedestrians.(28)

Gaze behavior in natural environments is affected by expectations that are derived through long-term learning. Using a virtual driving environment, Shinoda et al. asked participants to look for stop signs while driving an urban route.(29) Approximately 45 percent of the fixations fell in the general area of intersections during the simulated drive, and participants were more likely to detect stop signs placed near intersections than those placed in the middle of a block. Over time, drivers have learned that stop signs are more likely to appear near intersections and, as a result, drivers prioritize their allocation of gazes to these areas of the roadway.

The Tatler et al. review of the literature concludes that in natural vision, a consistent set of principles underlies eye guidance. These principles include relevance or reward potential, uncertainty about the state of the environment, and learned models of the environment.(21) Salience of environmental stimuli alone typically does not explain most eye gaze behavior in naturalistic environments.

In sum, most of the literature concerning eye gaze behavior in dynamic environments suggests that task demands tend to override visual salience in determining attention allocation. When extended to driving, it would be expected that visual attention will be directed toward task-relevant areas and objects (e.g., the roadway, other vehicles, speed limit signs, etc.) and other salient objects, such as billboards, will not necessarily capture attention. However, driving is a somewhat automatic process and conditions generally do not require constant undivided attention. As a result, salient stimuli, such as CEVMS, might capture driver attention and provide an unwarranted increase in driver distraction. The present study addresses this concern.

Research Questions

The present research evaluated the effects of CEVMS on driver visual behavior under actual roadway conditions in the daytime and at night. Roads containing CEVMS, standard billboards, and areas not containing off-premise advertising were selected. The CEVMS and standard billboards were measured with respect to luminance, location, size, and other relevant visual characteristics. The present study examined CEVMS as deployed in two United States cities. Unlike previous studies, the signs did not contain dynamic video or other dynamic elements. In addition, the eye tracking system used in this study has approximately a 2-degree level of resolution. This provided significantly more accuracy in determining what objects the drivers were looking at than in previous on-road studies examining looking behavior (recall that Lee et al. used video recordings of drivers' faces that, at best, examined gross eye movements).[9]

Two studies are reported. Each study was conducted in a different city. The two studies employed the same methodology. The studies' primary research questions were:

1. Do CEVMS attract drivers' attention away from the forward roadway and other driving relevant stimuli?

2. Do glances to CEVMS occur that would suggest a decrease in safety?

3. Do drivers look at CEVMS more than at standard billboards?

EXPERIMENTAL APPROACH

The study used a field research vehicle equipped with a non-intrusive eye tracking system. The vehicle was a 2007 Jeep® Grand Cherokee Sport Utility Vehicle. The eye tracking system used (SmartEye® vehicle-mounted infrared (IR) eye-movement measuring system) is shown in figure 1.[30] The system consists of two IR light sources and three face cameras mounted on the dashboard of the vehicle. The cameras and light sources are small in size, and are not attached to the driver in any manner. The face cameras are synchronized to the IR light sources and are used to determine the head position and gaze direction of the driver.

Figure 1. Eye tracking system camera placement.

As a part of this eye tracking system, the vehicle was outfitted with a three-camera panoramic scene monitoring system for capturing the forward driving scene. The scene cameras were mounted on the roof of the vehicle directly above the driver's head position. The three cameras together provided an 80-degree wide by 40-degree high field of forward view. The scene cameras captured the forward view area available to the driver through the left side of the windshield and a portion of the right side of the windshield. The area visible to the driver through the rightmost area of the windshield was not captured by the scene cameras.

The vehicle was also outfitted with equipment to record GPS position, vehicle speed, and vehicle acceleration. The equipment also recorded events entered by an experimenter and synchronized those events with the eye tracking and vehicle data. The research vehicle is pictured in figure 2.

Figure 2. FHWA's field research vehicle.

EXPERIMENTAL DESIGN OVERVIEW

The approach entailed the use of the instrumented vehicle in which drivers navigated routes in cities that presented CEVMS and standard billboards as well as areas without off-premise advertising. The participants were instructed to drive the routes as they normally would. The drivers were not informed that the study was about outdoor advertising, but rather that it was about examining drivers' glance behavior as they followed route guidance directions.

Site Selection

More than 40 cities were evaluated in the selection of the test sites. Locations with CEVMS displays were identified using a variety of resources that included State department of transportation contacts, advertising company Web sites, and a popular geographic information system. A matrix was developed that listed the number of CEVMS in each city. For each site, the number of CEVMS along limited access and arterial roadways was determined.

One criterion for site selection was whether the location had practical routes that pass by a number of CEVMS as well as standard off-premise billboards and could be driven in about 30 minutes. Other considerations included access to vehicle maintenance personnel/facilities, proximity to research facilities, and ease of participant recruitment. Two cities were selected: Reading, and Richmond.

Table 1 presents the 16 cities that were included on the final list of potential study sites.

Table 1. Distribution of CEVMS by roadway classification for various cities.

State	*Area*	*Limited Access*	*Arterial*	*Other* [1]	*Total*
VA	Richmond	4	7	0	11
PA	Reading	7	11	0	18
VA	Roanoke	0	11	0	11
PA	Pittsburgh	0	0	15	15
TX	San Antonio	7	2	6	15
WI	Milwaukee	14	2	0	16
AZ	Phoenix	10	6	0	16
MN	St. Paul/Minneapolis	8	5	3	16
TN	Nashville	7	10	0	17
FL	Tampa-St. Petersburg	7	11	0	18
NM	Albuquerque	0	19	1	20
PA	Scranton-Wilkes Barre	7	14	1	22
OH	Columbus	1	22	0	23
GA	Atlanta	13	11	0	24
IL	Chicago	22	2	1	25
CA	Los Angeles	3	71	4	78

(1) Other includes roadways classified as both limited access and arterial or instances where the road classification was unknown. *Source:* www.lamar.com and www.clearchannel.com

In both test cities, the following independent variables were evaluated:

- **The type of advertising.** This included CEVMS, standard billboards, and no off-premise advertising. (It should be noted that in areas with no off-premise advertising, it was still possible to encounter on-premise advertising; e.g., for gas stations, restaurants, and other miscellaneous stores and shops.)
- **Time of day.** This included driving in the daytime and at night.
- **The functional class of roadways in which off-premise advertising signs were located.** Roads were classified as either freeway or arterial. It was observed that the different road classes were correlated with the presence of other visual information that could affect the driver's glance behavior. For example, the visual environment on arterials may be more complex or cluttered than on freeways because of the close proximity of buildings, driveways, and on-premise advertising, etc.

READING

The first on-road study was conducted in Reading. This study examined the type of advertising (CEVMS, standard billboard, or no off-premise advertising), time of day (day or night) and road type (freeway or arterial) as independent variables. Eye tracking was used to assess where participants gazed and for how long while driving. The luminance and contrast of the advertising signs were measured to characterize the billboards in the current study.

METHOD

Selection of Data Collection Zone Limits

Data collection zones (DCZ) were defined on the routes that participants drove where detailed analyses of the eye tracking data were planned. The DCZ were identified that contained a CEVMS, a standard billboard, or no off-premise advertising.

The rationale for selecting the DCZ limits took into account the geometry of the roadway (e.g., road curvature or obstructions that blocked view of billboards) and the capabilities of the eye tracking system (2 degrees of resolution). At a distance of 960 ft (292.61 m), the average billboard in Reading was 12.8 ft (3.90 m) by 36.9 ft (11.25 m) and would subtend a horizontal visual angle of 2.20 degrees and a vertical visual angle of 0.76 degrees, and thus glances to the billboard would just be resolvable by an eye tracking system with 2 degrees of accuracy. Therefore 960 ft was chosen as the maximum distance from billboards at which a DCZ would begin. If the target billboard was not visible from 960 ft (292.61 m) due to roadway geometry or other visual obstructions, such as trees or an overpass, the DCZ was shortened to a distance that prevented these objects from interfering with the driver's vision of the billboard. In DCZs with target off-premise billboards, the end of the DCZ was marked when the target billboard left the view of the scene camera. If the area contained no off-premise advertising, the end of the DCZ was defined by a physical landmark leaving the view of the eye tracking systems' scene camera.

Table 2 shows the data collection zone limits used in this study.

Advertising Conditions

The type of advertising present in DCZs was examined as an independent variable. DCZs fell into one of the following categories, which are listed in the second column of table 2:

- **CEVMS**. These were DCZs that contained one target CEVMS. Two CEVMS DCZs were located on freeways and two were located on arterials. Figure 3 and figure 4 show examples of CEVMS DCZs with the CEVMS highlighted in the pictures.

- **Standard billboard**. These were DCZs that contained one target standard billboard. Two standard billboard DCZs were located on freeways and two were located on arterials. Figure 5 and figure 6 show examples of standard billboard DCZs; the standard billboards are highlighted in the pictures.

- **No off-premise advertising conditions**. These DCZs contained no off-premise advertising. One of these DCZs was on a freeway (see figure 7) and the other was on an arterial (see figure 8).

Table 2. Inventory of target billboards with relevant parameters.

DCZ	*Advertising Type*	*Copy Dimensions (ft)*	*Side of Road*	*Setback from Road (ft)*	*Other Standard Billboards*	*Approach Length (ft)*	*Type of Roadway*
1	CONTROL	N/A	N/A	N/A	N/A	786	Freeway
6	CONTROL	N/A	N/A	N/A	N/A	308	Arterial
3	CEVMS	10'6" x 22'9"	L	12	0	375	Arterial
5	CEVMS	14'0" x 48'0"	L	133	1	853	Freeway
9	CEVMS	10'6" x 22'9"	R	43	0	537	Arterial
10	CEVMS	14'0" x 48'0"	R	133	1	991	Freeway
2	Standard	14'0" x 48'0"	L	20	0	644	Arterial
7	Standard	14'0" x 48'0"	R	35	1	774	Freeway
8	Standard	10'6" x 22'9"	R	40	1	833	Arterial
4	Standard	14'0" x 48'0"	L	10	0	770	Freeway

**N/A indicates that there were no off-premise advertising in these areas and these values are undefined.*

Figure 3. DCZ with a target CEVMS on a freeway.

Figure 4. DCZ with a target CEVMS on an arterial.

Figure 5. DCZ with a target standard billboard on a freeway.

Figure 6. DCZ with a target standard billboard on an arterial.

Figure 7. DCZ for the control condition on a freeway.

Figure 8. DCZ for the control condition on an arterial.

Photometric Measurement of Signs

Two primary metrics were used to describe the photometric characteristics of a sample of the CEVMS and standard billboards present at each location: luminance (cd/m^2) and contrast (Weber contrast ratio).

Photometric Equipment

Luminance was measured with a Radiant Imaging ProMetric 1600 Charge-Coupled Device (CCD) photometer with both a 50 mm and a 300 mm lenses. The CCD photometer provided a method of capturing the luminance of an entire scene at one time.

The photometric sensors were mounted in a vehicle of similar size to the eye tracking research vehicle. The photometer was located in the experimental vehicle as close to the driver's position as possible and was connected to a laptop computer that stored data as the images were acquired.

Measurement Methodology

Images of the billboards were acquired using the photometer manufacturer's software. The software provided the mean luminance of each billboard message. To prevent overexposure of images in daylight, neutral density filters were manually affixed to the photometer lens and the luminance values were scaled appropriately. Standard billboards were typically measured only once; however, for CEVMS multiple measures were taken to account for changing content.

Photometric measurements were taken during day and night. Measurements were taken by centering the billboard in the photometer's field of view with approximately the equivalent of the width of the billboard on each side and the equivalent of the billboard height above and below the sign. The areas outside of the billboards were included to enable contrast calculations.

Standard billboards were assessed at a mean distance of 284 ft (ranging from 570 ft to 43 ft). The CEVMS were assessed at a mean distance of 479 ft (ranging from 972 ft to 220 ft). To include the background regions of appropriate size, the close measurement distances required the use of the 50 mm lens whereas measurements made from longer distances required the 300 mm lens. A significant determinant of the measurement locations was the availability of accessible and safe places from which to measure.

The Weber contrast ratio was used because it characterizes a billboard as having negative or positive contrast when compared to its background area.[(31)] A negative contrast indicates the background areas have a higher mean luminance than the target billboard. A positive contrast indicates the target billboard has a higher mean luminance than the background. Overall, the absolute value of a contrast ratio simply indicates a difference in luminance between an item and its background. From a perceptual perspective luminance and contrast are directly related to the perception of brightness. For example, two signs with equal luminance may be perceived differently with respect to brightness because of differences in contrast.

Visual Complexity

Regan, Young, Lee and Gordon presented a taxonomic description of the various sources of driver distraction.[(32)] Potential sources of distraction were discussed in terms of: things brought into the vehicle; vehicle systems; vehicle occupants; moving objects or animals in the vehicle; internalized activity; and external objects, events, or activities. The external objects may include buildings, construction zones, billboards, road signs, vehicles, and so on. Focusing on the potential for information outside the vehicle to attract (or distract) the driver's attention, Horberry and Edquist developed a taxonomy for out-of-the-vehicle visual information. This suggested taxonomy includes four groupings of visual information: built roadway, situational entities, natural environment, and built environment.[(33)] These two taxonomies provide an organizational structure for conducting research; however, they do not currently provide a systematic or quantitative way of classifying the level of clutter or visual complexity present in a visual scene.

The method proposed by Rozenholtz, Li, and Nakano provides quantitative and perhaps reliable measures of visual clutter.[(34)] Their approach measures the feature congestion in a visual image. The implementation of the feature congestion measure involves four stages: (1) compute local feature covariance at multiple scales and compute the volume of the local covariance ellipsoid, (2) combine clutter across scale, (3) combine clutter across feature types, and (4) pool over space to get a single measure of clutter for each input image. The implementation that was used employed color, orientation and luminance contrast as features. Presumably, less cluttered images can be visually coded more efficiently than cluttered images. For example, visual clutter can cause decreased recognition performance and greater difficulty in performing visual search.[35]

Participants

In the present study participants were recruited at public libraries in the Reading area. A table was set up so that recruiters could discuss the requirements of the experiment with candidates. Individuals who expressed interest in participating were asked to complete a pre-screening form, a record of informed consent, and a department of motor vehicles form consenting to release of their driving record.

All participants were between 18 and 64 years of age and held a valid driver's license. The driving record for each volunteer was evaluated to eliminate drivers with excessive violations. The criteria for excluding drivers were as follows: (a) more than one violation in the preceding year; (b) more than three recorded violations; and (c) any driving while intoxicated violation.

Forty-three individuals were recruited to participate. Of these, five did not complete the drive because the eye tracker could not be calibrated to track their eye movements accurately. Data from an additional seven participants were excluded as the result of equipment failures (e.g., loose camera). In the end, usable data was collected from 31 participants (12 males, M = 46 years; 19 females, M = 47 years). Fourteen participants drove at night and 17 drove during the day.

Procedures

Data were collected from two participants per day (beginning at approximately 12:45 p.m. and 7:00 p.m.). Data collection began on September 18, 2009, and was completed on October 26, 2009.

Pre-Data Collection Activities

Participants were greeted by two researchers and asked to complete a fitness to drive questionnaire. This questionnaire focused on drivers' self-reports of alertness and use of substances that might impair driving (e.g., alcohol). All volunteers appeared fit.

Next, the participant and both researchers moved to the eye tracking calibration location and the test vehicle. The calibration procedure took approximately 20 minutes. Calibration of the eye tracking system entailed development of a profile for each participant. This was accomplished by taking multiple photographs of the participant's face as they slowly rotate their head from side to side. The saved photographs include points on the face for subsequent real-time head and eye tracking. Marked coordinates on the face photographs were edited by the experimenter as needed to improve the real-time face tracking. The procedure also included gaze calibration in which participants gazed at nine points on a wall. These points had been carefully plotted on the wall and correspond to the points in the eye tracking system's world model. Gaze calibration relates the individual participant's gaze vectors to known points in the real world. The eye tracking system uses two pulsating infrared sources mounted on the dashboard to create two corneal glints that are used to calculate gaze direction vectors. The glints were captured at 60 Hz. A second set of cameras (scene cameras), fixed on top of the car close to the driver's viewpoint, were used to produce a video scene of the area ahead. The scene cameras recorded at 25 Hz. A parallax correction algorithm compensated for the distance between the driver's viewpoint and the scene cameras so that later processing could use the gaze vectors to show where in the forward scene the driver was gazing.

If it was not possible to calibrate the eye tracking system to a participant, the participant was dismissed and paid for their time. Causes of calibration failure included reflections from eye glasses, participant height (which put their eyes outside the range of the system), and eyelids that obscure a portion of the pupil.

Practice

After eye-tracker calibration, a short practice drive was made. Participants were shown a map of the route and written turn-by-turn directions prior to beginning the practice drive. Throughout the drive, verbal directions were provided by a GPS device.

During the practice drive, a researcher in the rear seat of the vehicle monitored the accuracy of eye tracking. If the system was tracking poorly, additional calibration was performed. If the calibration could not be improved, the participant was paid for their time and dismissed.

Data Collection

Participants drove two test routes (referred to as route A and B). Each route required 25 to 30 minutes to complete and included both freeway and arterial segments. Route A was 13 miles long and contained 6 DCZs. Route B was 16 miles long and contained 4 DCZs. Combined, participants drove in a total of 10 DCZs. Similar to the practice drive, participants were shown a map of the route and written turn-by-turn directions. A GPS device provided turn-by-turn guidance during the drive. Roughly one half of the participants drove route A first and the remaining participants began with route B. A 5 minute break followed the completion of the first route.

During the drives, a researcher in the front passenger seat assisted the driver when additional route guidance was required. The researcher was also tasked with recording near misses and driver errors if these occurred. The researcher in the rear seat monitored the performance of the eye tracker. If the eye tracker performance became unacceptable (i.e., loss of calibration), then the researcher in the rear asked the participant to park in a safe location so that the eye tracker could be recalibrated. This recalibration typically took a minute or two to accomplish.

Debriefing

After driving both routes, the participants provided comments regarding their drives. The comments were in reference to the use of a navigation system. No questions were asked about billboards. The participants were given $120.00 in cash for their participation.

DATA REDUCTION

Eye Tracking Measures

The Multiple-Analysis of Psychophysical and Performance Signals (MAPPS™) software was used to reduce the eye tracking data.[36] The software integrates the video output from the scene cameras with the output from the eye tracking software (e.g., gaze vectors). The analysis software provides an interface in which the gaze vectors determined by the eye tracker can be related to areas or objects in the scene camera view of the world. Analysts can indicate regions of interest (ROIs) in the scene camera views and the analysis software then assigns gaze vectors to the ROIs.

Figure 9 shows a screen capture from the analysis software in which static ROIs have been identified. These static ROIs slice up the scene camera views into six areas. The software also allows for the construction of dynamic ROIs. These are ROIs that move in the video because of own-vehicle movement (e.g., a sign changes position on the display as it is approached by the driver) or because the object moves over time independent of own-vehicle movement (e.g., pedestrian walking along the road, vehicle entering or exiting the road).

Static ROIs need only be entered once for the scenario being analyzed whereas dynamic ROIs need to be entered several times for a given DCZ depending on how the object moves along the video scene; however, not every frame needs to be coded with a dynamic ROI since the software interpolates across frames using the 60-Hz data to compute eye movement statistics.

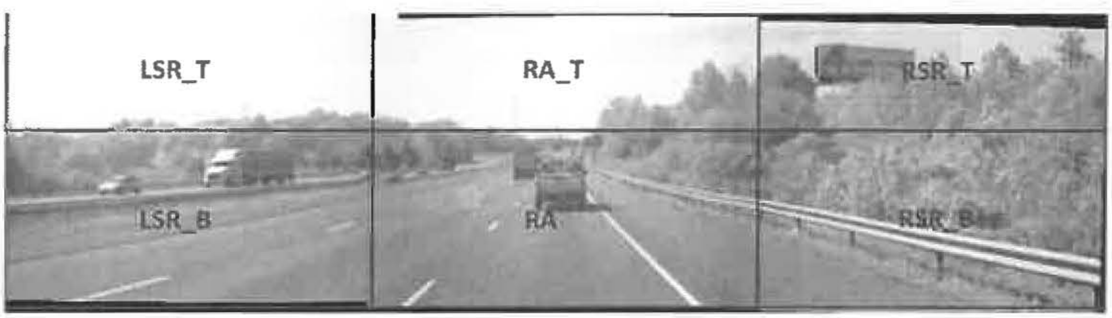


Figure 9. Screen capture showing static ROIs on a scene video output.

The following ROIs were defined with the analysis software:

Static ROIs

These ROIs were entered once into the software for each participant. The static ROIs for the windshield were divided into top and bottom to have more resolution during the coding process. The subsequent analyses in the report combines the top and bottom portion of these ROIs since it appeared that this additional level of resolution was not needed in order to address research questions:

- Road ahead: bottom portion (approximately 2/3) of the area of the forward roadway (center camera).

- Road ahead top: top portion (approximately 1/3) of the area of the forward roadway (center camera).

- Right side of road bottom: bottom portion (approximately 2/3) of the area to the right of the forward roadway (right camera).

- Right side of road top: top portion (approximately 1/3) of the area to the right of the forward roadway (right camera).

- Left side of road bottom (LSR_B): bottom portion (approximately 2/3) of the area to the left of the forward roadway (left camera).

- Left side of road bottom (LSR_T): top portion (approximately 1/3) of the area to the left of the forward roadway (left camera).

- Inside vehicle: below the panoramic video scene (outside of the view of the cameras, but eye tracking is still possible).

- Top: above the panoramic video scene (outside of the view of the cameras, but eye tracking is still possible).

Dynamic ROIs

These ROIs are created multiple times within a DCZ for stimuli that move relative to the driver:

- Driving-related safety risk: vehicle which posed a potential safety risk to the driver, defined as a car that is/may turn into the driver's direction of travel at a non-signalized or non-stop-controlled intersection (e.g., a car making a U-turn, a car waiting to turn right, or a car waiting to turn left). These vehicles were actively turning or entering the roadway or appeared to be in a position to enter the roadway.

- Target standard billboard: target standard billboard that defines the start and end of the DCZ.

- Other standard billboard: standard billboard(s) located in the DCZ, other than the target standard billboard or the target digital billboard.

- CEVMS: target digital billboard that defines the start and end of the DCZ.

The software determines the gaze intersection for each 60 Hz frame and assigns it to an ROI. In subsequent analyses and discussion, gaze intersections are referred to as gazes. Since ROIs may overlap, the software allows for the specification of priority for each ROI such that the ROI with the highest priority gets the gaze vector intersection assigned to it. For example, an ROI for a CEVMS may also be in the static ROI for the road ahead.

The 60 Hz temporal resolution of the eye tracking software does not provide sufficient information to make detailed analysis of saccade characteristics,[1] such as latency or speed. The analysis software uses three parameters in the determination of a fixation: a fixation radius, fixation duration, and a time out. The determination begins with a single-gaze vector intersection. Any subsequent intersection within a specified radius will be considered part of a fixation if the minimum fixation duration criterion is met. The radius parameter used in this study was 2 degrees and the minimum duration was 100 ms. The 2-degree selection was based on the estimated accuracy of the eye tracking system, as recommended by Recarte and Nunes.(37) The 100 ms minimum duration is consistent with many other published studies; however, some investigators use minimums of as little as 60 ms.(37,38) Because of mini-saccades and noise in the eye tracking system, it is possible to have brief excursions outside the 2 degree window for a fixation. In this study, an excursion time outside the 2-degree radius of less than 90 ms was ignored. Once the gaze intersection fell outside the 2-degree radius of a fixation for more than 90 ms, the process of identifying a fixation began anew.

Other Measures

Driving Behavior Measures

During data collection, the front-seat researcher observed the driver's behavior and the driving environment. The researcher used the following subjective categories in observing the participant's driving behavior:

- **Driver Error:** signified any error on behalf of the driver in which the researcher felt slightly uncomfortable, but not to a significant degree (e.g., driving on an exit ramp too quickly, turning too quickly).
- **Near Miss:** signified any event in which the researcher felt uncomfortable due to driver response to external sources (e.g., slamming on brakes, swerving). A near miss is the extreme case of a driver error.
- **Incident:** signified any event in the roadway which may have had a potential impact on the attention of the driver and/or the flow of traffic (e.g., crash, emergency vehicle, animal, construction, train).

These observations were entered into a notebook computer linked to the research vehicle data collection system.

Level of Service Estimates

For each participant and each DCZ the analyst estimated the level of service of the road as they reviewed the scene camera video. One location per DCZ was selected (approximately halfway through the DCZ) where the number of vehicles in front of the research vehicle was counted. The procedure entailed (1) counting the number of travel lanes visible in the video, (2) using the

[1] During visual scanning, the point of gaze alternates between brief pauses (ocular fixations) and rapid shifts (saccades).

skip lines on the road to estimate the approximate distance in front of the vehicle that constituted the analysis zone, and (3) counting the number of vehicles present within the analysis zone. Vehicle density was calculated with the formula:

Vehicle Density = [(Number of Vehicles in Analysis Zone)/(Distance of Analysis Zone in ft/5280)]/Number of Lanes.

Vehicle density is the number of vehicles per mile per lane.

Vehicle Speed

The speed of the research vehicle was recorded with GPS and a distance measurement instrument. Vehicle speed was used principally to ensure that the eye tracking data was recorded while the vehicle was in motion.

RESULTS

Results are presented with respect to the photometric measures of signs, the visual complexity of the DCZs, and the eye tracking measures. Photometric measurements were taken and analyzed to characterize the billboards in the study based on their luminance and contrasts, which are related to how bright the signs are perceived to be by drivers.

Photometric Measurements

Luminance

The mean daytime luminance of both the standard billboards and CEVMS was greater than at night. Nighttime luminance measurements reflect the fact that CEVMS use illuminating LED components while standard billboards are often illuminated from below by metal halide lamps. At night, CEVMS have a greater average luminance than standard billboards. Table 3 presents summary statistics for luminance as a function of time of day for the CEVMS and standard billboards.

Contrast

The daytime and nighttime Weber contrast ratios for both types of billboards are shown in table 3. Both CEVMS and standard billboards had contrast ratios that were close to zero (the surroundings were about equal in brightness to the signs) during the daytime. On the other hand, at night the CEVMS and standard billboards had positive contrast ratios (the signs were brighter than the surrounding), with the CEVMS having higher contrast than the standard billboards.

Table 3. Summary of luminance (cd/m²) and contrast (Weber ratio) measurements.

	Luminance (cd/m²)		*Contrast*	
Day	*Mean*	*St. Dev.*	*Mean*	*St .Dev.*
CEVMS	2126	798.81	-0.10	0.54
Standard Billboard	2993	2787.22	-0.27	0.84
Night				
CEVMS	56.00	23.16	73.72	56.92
Standard Billboard	17.80	17.11	36.01	30.93

Visual Complexity

The DCZs were characterized by their overall visual complexity or clutter. For each DCZ, five pictures were taken from the driver's viewpoint at various locations within the DCZ. In Reading, the pictures were taken from 2:00 p.m. to 4:00 p.m. In Richmond, one route was photographed from 11:00 a.m. to noon and the other from 2:30 p.m. to 3:30 p.m. The pictures were taken at the start of the DCZ, quarter of the way through, half of the way through, three quarters of the way through, and at the end of the DCZ. The photographs were analyzed with MATLAB® routines that computed a measure of feature congestion for each image. Figure 10 shows the mean feature congestion measures for each of the DCZ environments. The arterial control condition was shown to have the highest level of clutter as measured by feature congestion. An analysis of variance was performed on the feature congestion measure to determine if the conditions differed significantly from each other. The four conditions with off-premise advertising did not differ significantly with respect to feature congestion; $F(3,36) = 1.25, p > 0.05$. Based on the feature congestion measure, the results indicate that the four conditions with off-premise advertising were equated with respect to the overall visual complexity of the driving scenes.

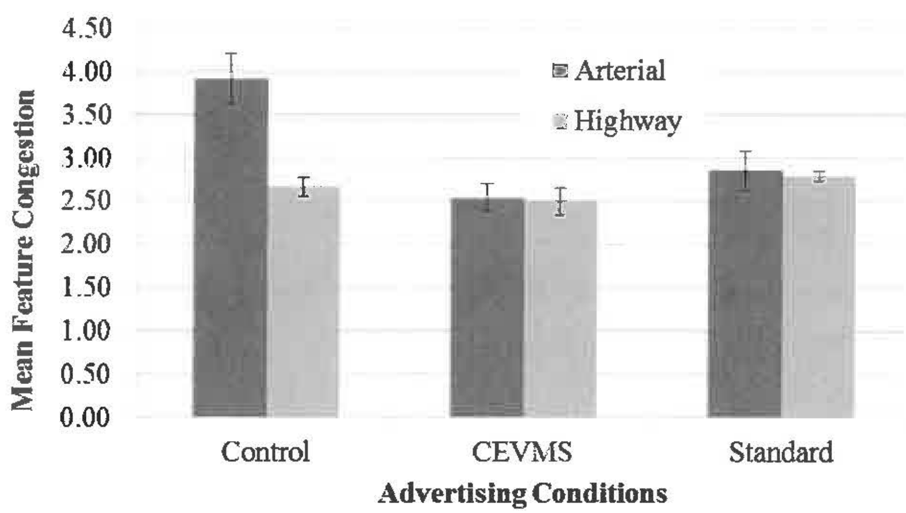


Figure 10. Mean feature congestion as a function of advertising condition and road type (standard errors for the mean are included in the graph).

Effects of Billboards on Gazes to the Road Ahead

For each 60 Hz frame, a determination was made as to the direction of the gaze vector. Previous research has shown that gazes do not need to be separated into saccades and fixations before calculating such measures as percent of time or the probability of looking to the road ahead.[39] This analysis examines the degree to which drivers gaze toward the road ahead across the different advertising conditions as a function of road type and time of day. Gazing toward the road ahead is critical for driving, and so the analysis examines the degree to which gazes toward this area are affected by the independent variables (advertising type, type of road, and time of day) and their interactions.

Generalized estimating equations (GEE) were used to analyze the probability of a participant gazing at driving-related information.[40,41] The data for these analyses were not normally distributed and included repeated measures. The GEE model is appropriate for these types of data and analyses. Note that for all results included in this report, Wald statistics were the chosen alternative to likelihood ratio statistics because GEE uses quasi-likelihood instead of maximum likelihood.[42] For this analysis, road ahead included the following ROIs (as previously described and displayed in figure 9): road ahead, road ahead top, and driving-related risks. A logistic regression model for repeated measures was generated by using a binomial response distribution and Logit (i.e., log odds) link function. Only two possible outcomes are allowed when selecting a binomial response distribution. Thus, a variable (RoadAhead) was created to classify a participant's gaze behavior. If the participant gazed toward the road ahead, road ahead top, or driving-related risks, then the value of RoadAhead was set to one. If the participant gazed at any other object in the panoramic scene, then the value of RoadAhead was set to zero. Logistic regression typically models the probability of a success. In the current analysis, a success would be a gaze to road ahead information (RoadAhead = 1) and a failure would be a gaze toward non-road ahead information (RoadAhead = 0). The resultant value was the probability of a participant gazing at road-ahead information.

Time of day (day or night), road type (freeway or arterial), advertising condition (CEVMS, standard billboard, or control), and all corresponding second-order interactions were explanatory variables in the logistic regression model. The interaction of advertising condition by road type was statistically significant, $\chi^2(2) = 6.3$, $p = 0.043$. Table 4 shows the corresponding probabilities for gazing at the road ahead as a function of advertising condition and road type.

Table 4. The probability of gazing at the road ahead as a function of advertising condition and road type.

Advertising Condition	*Arterial*	*Freeway*
Control	0.92	0.86
CEVMS	0.82	0.73
Standard	0.80	0.77

Follow-up analyses for the interaction used Tukey-Kramer adjustments with an alpha level of 0.05. The arterial control condition had the greatest probability of looking at the road ahead (M = 0.92). This probability differed significantly from the remaining five probabilities. On arterials, the probability of gazing at the road ahead did not differ between the CEVMS (M = 0.82) and the standard billboard (M = 0.80) DCZs. In contrast, there was a significant difference in this probability on freeways, where standard billboard DCZs yielded a higher probability (M = 0.77) than CEVMS DCZs (M = 0.73). The probability of gazing at the road ahead was also significantly higher in the freeway control DCZ (M = 0.86) than in either of the corresponding freeway off-premise advertising DCZs. The probability of gazing at road-ahead information in arterial CEVMS DCZs was not statistically different from the same probability in the freeway control DCZ.

Additional descriptive statistics were computed to determine the probability of gazing at the various ROIs that were defined in the panoramic scene. Some of the ROIs depicted in figure 9 were combined in the following fashion for ease of analysis:

- Road ahead, road ahead top, and driving-related risks combined to form *road ahead.*
- Left side of road bottom and left side of road top combined to form *left side of vehicle.*
- Right side of road bottom and right side of road top combined to form *right side of vehicle.*
- Inside vehicle and top combined to form *participant vehicle.*

Table 5 presents the probability of gazing at the different ROIs.

Table 5. Probability of gazing at ROIs for the three advertising conditions on arterials and freeways.

Road Type	*ROI*	*CEVMS*	*Standard Billboard*	*Control*
Arterial	*CEVMS*	0.07	N/A	N/A
	Left Side of Vehicle	0.06	0.06	0.02
	Road ahead	0.82	0.80	0.92
	Right Side of Vehicle	0.03	0.06	0.04
	Standard Billboard	N/A	0.03	N/A
	Participant Vehicle	0.03	0.05	0.02
Freeway	*CEVMS*	0.05	N/A	N/A
	Left Side of Vehicle	0.08	0.07	0.04
	Road ahead	0.73	0.77	0.86
	Right Side of Vehicle	0.09	0.02	0.05
	Standard Billboard	0.02*	0.09	N/A
	Participant Vehicle	0.04	0.05	0.05

* The CEVMS DCZs on freeways each contained one visible standard billboard.

The probability of gazing away from the forward roadway ranged from 0.08 to 0.27. In particular, the probability of gazing toward a CEVMS was greater on arterials (M = 0.07) than on freeways (M = 0.05). In contrast, the probability of gazing toward a target standard billboard was greater on freeways (M = 0.09) than on arterials (M = 0.03).

Fixations to CEVMS and Standard Billboards

About 2.4 percent of the fixations were to CEVMS. The mean fixation duration to a CEVMS was 388 ms and the maximum duration was 1,251 ms. Figure 11 shows the distribution of fixation durations to CEVMS during the day and night. In the daytime, the mean fixation duration to a CEVMS was 389 ms and at night it was 387 ms. Figure 12 shows the distribution of fixation durations to standard billboards. Approximately 2.4 percent of fixations were to standard billboards. The mean fixation duration to standard billboards was 341 ms during the daytime and 370 ms at night. The maximum fixation duration to standard billboards was 1,284 ms (which occurred at night). For comparison purposes, figure 13 shows the distribution of fixation durations to the road ahead (i.e., top and bottom road ahead ROIs) during the day and night. In the daytime, the mean fixation duration to the road ahead was 365 ms and at night it was 390 ms.

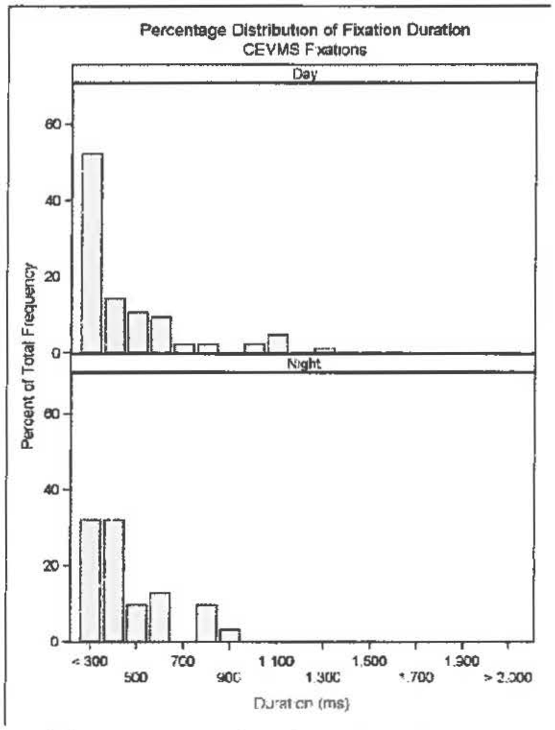


Figure 11. Distribution of fixation duration for CEVMS in the daytime and nighttime.

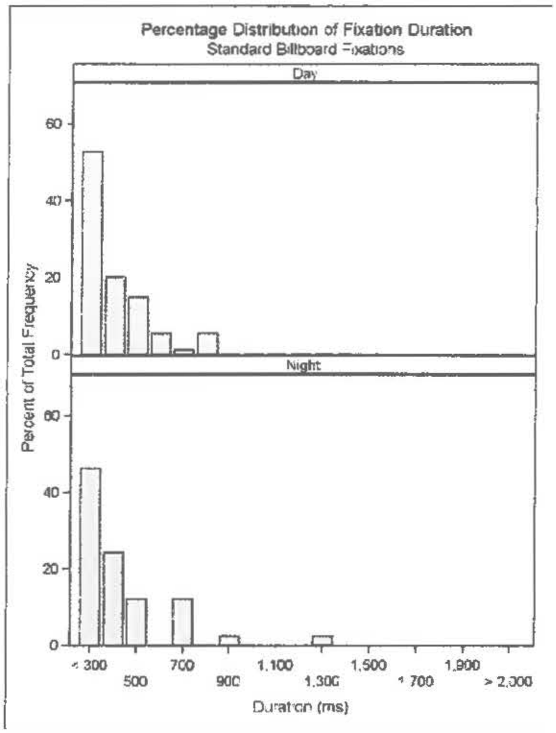


Figure 12. Distribution of fixation duration for standard billboards in the daytime and nighttime.

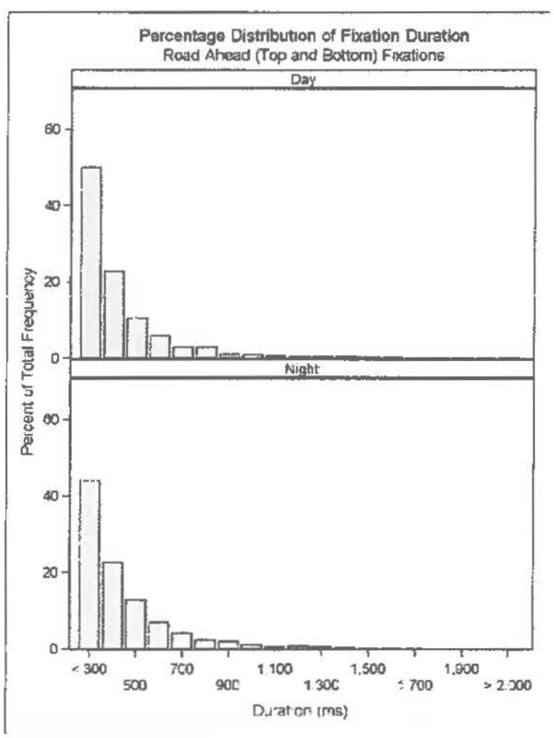


Figure 13. Distribution of fixation duration for road ahead (i.e., top and bottom road ahead ROIs) in the daytime and nighttime.

Dwell times on CEVMS and standard billboards were also examined. Dwell time is the duration of back-to-back fixations to the same ROI.[43,44] The dwell times represent the cumulative time for the back-to-back fixations. Whereas there may be no long, single fixation to a billboard, there might still be multiple fixations that yield long dwell times. There were a total of 25 separate instances of multiple fixations to CEVMS with a mean of 2.4 fixations (minimum of 2 and maximum of 5). The 25 dwell times came from 15 different participants distributed across four different CEVMS. The mean duration of these dwell times was 994 ms (minimum of 418 ms and maximum of 1,467 ms).

For standard billboards, there were a total of 17 separate dwell times with a mean of 3.47 sequential fixations (minimum of 2 fixations and maximum of 8 fixations). The 17 dwell times came from 11 different participants distributed across 4 different standard billboards. The mean duration of these multiple fixations was 1,172 ms (minimum of 418 ms and maximum of 3,319 ms). There were three dwell-time durations that were greater than 2,000 ms. These are described in more detail below.

In some cases several dwell times came from the same participant. In order to compute a statistic on the difference between dwell times for CEVMS and standard billboards, average dwell times were computed per participant for the CEVMS and standard billboard conditions. These average values were used in a t-test assuming unequal variances. The difference in average dwell time between CEVMS (M = 981 ms) and standard billboards (M= 1,386 ms) was not statistically significant, $t(12) = -1.40$, $p > .05$.

Figure 14 through figure 23 show heat maps for the dwell-time durations to the standard billboards that were greater than 2,000 ms. These heat maps are snapshots from the DCZ and attempt to convey in two dimensions the pattern of gazes that took place in a three dimensional world. The heat maps are set to look back approximately one to two seconds and integrate over time where the participant was gazing in the scene camera video. The green color in the heat map indicates the concentration of gaze over the past one to two seconds. The blue line indicates the gaze trail over the past one to two seconds.

Figure 14 through figure 16 are for a DCZ on an arterial at night. The standard billboard was on the right side of the road (indicated by a pink rectangle). There were eight fixations to this billboard, and the single fixations were between 200 to 384 ms in duration. The dwell time for this billboard was 2,019 ms. At the start of the DCZ (see figure 14), the driver was directing his/her gaze to the forward roadway. Approaching the standard billboard, the driver began to fixate on the billboard. However, the billboard was still relatively close to the road ahead ROI.

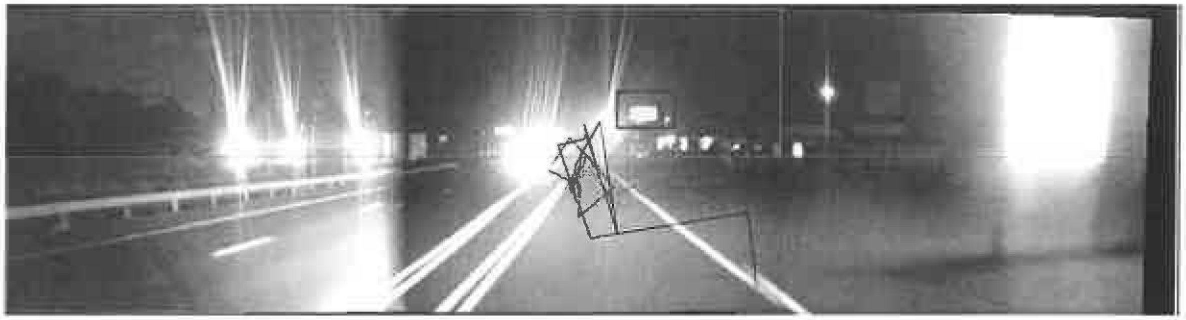


Figure 14. Heat map for the start of a DCZ for a standard billboard at night on an arterial.

Figure 15. Heat map for the middle of a DCZ for a standard billboard at night on an arterial.

Figure 16. Heat map near the end of a DCZ for a standard billboard at night on an arterial.

Figure 17 through figure 19 are for a DCZ on a freeway at night. The standard billboard was on the right side of the road (indicated by a green rectangle). There were six consecutive fixations to this billboard, and the single fixations were between 200 and 801 ms in duration. The dwell time for this billboard was 2,753 ms. At the start of the DCZ (see figure 17), the driver was directing his/her gaze to a freeway guide sign in the road ahead and the standard billboard was to the left of the freeway guide sign. As the driver approached the standard billboard, his/her gaze was directed toward the billboard. The billboard was relatively close to the top and bottom road ahead ROIs. Near the end of the DCZ (see figure 19), the billboard was accurately portrayed as being on the right side of the road.

Figure 17. Heat map for start of a DCZ for a standard billboard at night on a freeway.

Figure 18. Heat map for middle of a DCZ for a standard billboard at night on a freeway.

Figure 19. Heat map near the end of a DCZ for a standard billboard at night on a freeway.

Figure 20 through figure 23 are for a DCZ on a freeway during the day. The standard billboard was on the right side of the road (indicated by a pink rectangle). This is the same DCZ that was discussed in figure 17 through figure 19. There were six consecutive fixations to this billboard, and the single fixations were between 217 and 767 ms in duration. The dwell time for this billboard was 3,319 ms. At the start of the DCZ (see figure 20), the driver was principally directing his/her gaze to the road ahead. Figure 21 and figure 22 show the location along the DCZ where gaze was directed toward the standard billboard. The billboard was relatively close to the top and bottom road-ahead ROIs. As the driver passed the standard billboard, his/her gaze returned to the road ahead (see figure 23).

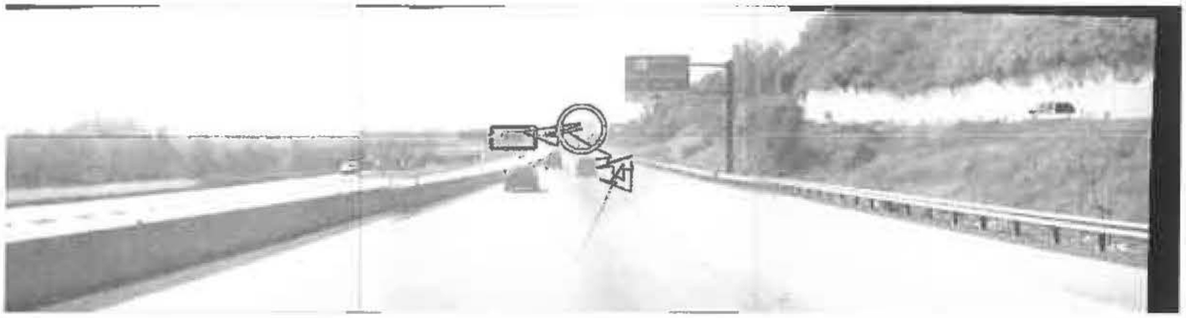


Figure 20. Heat map for the start of a DCZ for a standard billboard in the daytime on a freeway.

Figure 21. Heat map near the middle of a DCZ for a standard billboard in the daytime on a freeway.

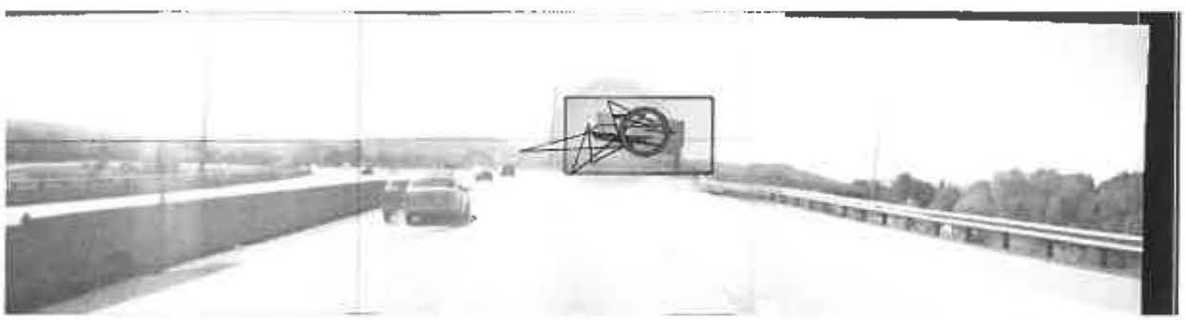


Figure 22. Heat map near the end of DCZ for standard billboard in the daytime on a freeway.

Figure 23. Heat map at the end of DCZ for standard billboard in the daytime on a freeway.

Comparison of Gazes to CEVMS and Standard Billboards

The GEE were used to analyze whether a participant gazed more toward CEVMS than toward standard billboards, given that the participant was gazing at off-premise advertising. With this analysis method, a logistic regression model for repeated measures was generated by using a binomial response distribution and Logit link function. First, the data was partitioned to include only those instances when a participant was gazing toward off-premise advertising (either to a CEVMS or to a standard billboard); all other gaze behavior was excluded from the input data set. Only two possible outcomes are allowed when selecting a binomial response distribution. Thus, a variable (SBB_CEVMS) was created to classify a participant's gaze behavior. If the participant gazed toward a CEVMS, the value of SBB_CEVMS was set to one. If the participant gazed toward a standard billboard, then the value of SBB_CEVMS was set to zero.

Logistic regression typically models the probability of a success. In the current analysis, a success would be a gaze to a CEVMS (SBB_CEVMS = 1) and a failure would be a gaze to a standard billboard (SBB_CEVMS = 0).[2] A success probability greater than 0.5 indicates there were more successes than failures in the sample. Therefore, if the sample probability of the response variable (i.e., SBB_CEVMS) was greater than 0.5, this would show that participants gazed more toward CEVMS than toward standard billboards when the participants gazed at off-premise advertising. In contrast, if the sample probability of the response variable was less than 0.5, then participants showed a preference to gaze more toward standard billboards than toward CEVMS when directing gazes to off-premise advertising.

Time of day (i.e., day or night), road type (i.e., freeway or arterial), and the corresponding interaction were explanatory variables in the logistic regression model. Road type was the only predictor to have a significant effect, $\chi^2(1) = 13.17, p < 0.001$. On arterials, participants gazed more toward CEVMS than toward standard billboards (M = 0.63). In contrast, participants gazed more toward standard billboards than toward CEVMS when driving on freeways (M = 0.33).

Observation of Driver Behavior

No near misses or driver errors were observed in Reading.

Level of Service

The mean vehicle densities were converted to level of service as shown in table 6.[45] As expected, less congestion occurred at night than in the day. In general, there was traffic during the data collection runs. Review of the scene camera data verified that all eye tracking data within the DCZs were recorded while the vehicle was in motion.

---

[2] Success and failure are not used to reflect the merits of either type of sign, but only for statistical purposes.

Table 6. Level of service as a function of advertising type, road type, and time of day.

	Arterial		*Freeway*	
	Day	Night	Day	Night
Control	B	A	C	B
CEVMS	C	A	B	A
Standard	A	A	B	A

DISCUSSION OF READING RESULTS

Overall the probability of gazing at the road ahead was high and similar in magnitude to what has been found in other field studies addressing billboards.[11,9,12] For the DCZs on freeways, CEVMS showed a lower proportion of gazes to the road ahead than the standard billboard condition, and both off-premise advertising conditions had lower probability of gazes to the road ahead than the control. On the other hand, on the arterials, the CEVMS and standard billboard conditions did not differ from each other but were significantly different from their respective control condition. Though the CEVMS condition on the freeway had the lowest proportion of gazes to the road ahead, in this condition there was a lower proportion of gazes to CEVMS as compared to the arterials (see table 5 for the trade-off of gazes to the different ROIs). A greater proportion of gazes to other ROIs (left side of the road, right side of the road, and participant vehicle) contributed to the decrease in proportion of gazes to the road ahead. Also, for the CEVMS on freeways, there were a few gazes to a standard billboard located in the same DCZ and there were more gazes distributed to the left and right side of the road than in standard billboard and control conditions. The gazes to ROIs other than CEVMS contributed to the lower probability of gazes to the road ahead in this condition.

The control condition on the arterial had buildings along the sides of the road and generally presented a visually cluttered area. As was presented earlier, the feature congestion measure computed on a series of photographs from each DCZ showed a significantly higher feature congestion score for the control condition on arterials as compared to all of the other DCZs. Nevertheless, the highest probability for gazing at the road ahead was seen in the control condition on the arterial.

The area with the highest feature congestion, especially on the sides of the road, had the highest probability for drivers looking at the road ahead. Bottom-up or stimulus driven measures of salience or visual clutter have been useful in predicting visual search and the effects of visual salience in laboratory tasks.[34,46] These measures of salience basically consider the stimulus characteristics (e.g., size, color, brightness) independent of the requirements of the task or plans that an individual may have. Models of visual salience may predict that buildings and other prominent features on the side of the road may be visually salient objects and thus would attract a driver's attention.[47] Figure 24 shows an example of a roadway photograph that was analyzed with the Salience Toolbox based on the Itti et al. implementation of a saliency based model of bottom-up attention.[48,49] The numbered circles in figure 24 are the first through fifth salient areas selected by the software. Based on this software, the most salient areas in the photographs are the buildings on the sides of the road where the road ahead (and a car) is the fifth selected salient area.

Figure 24. Example of identified salient areas in a road scene based on bottom-up analysis.

It appears that in the present study participants principally kept their eyes on the road even in the presence of visual clutter on the sides of the road, which supports the hypothesis that drivers tend to look toward information relevant to the task at hand.[50,26,22] In the case of the driving task, visual clutter may be more of an issue with respect to crowding that may affect the driver's ability to detect visual information in the periphery.[51] Crowding is generally defined as the negative effect of nearby objects or features on visual discrimination of a target.[52] Crowding impairs the ability to recognize objects in clutter and principally affects perception in peripheral vision. However, crowing effects were not analyzed in the present study.

Stimulus salience, clutter, and the nature of the task at hand interact in visual perception. For tasks such as driving, the task demands tend to outweigh stimulus salience when it comes to gaze control. Clutter may be more of an issue with the detection and recognition of objects in peripheral vision (e.g., detecting a sign on the side of the road) that are surrounded by other stimuli that result in a crowding effect.

The mean fixation durations to CEVMS, standard billboards, and the road ahead were found to be very similar. Also, there were no long fixations (greater than 2,000 ms) to CEVMS or standard billboards. The examination of multiple sequential fixations to CEVMS yielded average dwell times that were less than 1,000 ms. However, when examining the tails of the distribution, there were three dwell times to standard billboards that were in excess of 2,000 ms (the three dwell times came from three different participants to two different billboards). These three standard billboards were dwelled upon when they were near the road ahead area but drivers quit gazing at the signs as they neared them and the signs were no longer near the forward field of view. Though there were three dwell times for standard billboards greater than 2,000 ms, the difference in average dwell times for CEVMS and standard billboards was not significant.

Using a gaze duration of 2,000 ms away from the road ahead as a criterion indicative of increased risk has been developed principally as it relates to looking inside the vehicle to in-vehicle information systems and other devices (e.g., for texting) where the driver is indeed looking completely away from the road ahead.[14,53,54] The fixations to the standard billboards in the present case showed a long dwell time for a billboard. However, unlike gazing or fixating inside the vehicle, the driver's gaze was within the forward roadway where peripheral vision could be used to monitor for hazards and for vehicle control. Peripheral vision has been shown to be important for lane keeping, visual search orienting, and monitoring of surrounding objects.[55,56]

The results showed that drivers were more likely to gaze at CEVMS on arterials and at standard billboards on freeways. Though every attempt was made to select CEVMS and standard billboard DCZs that were equated on important parameters (e.g., which side of the road the sign was located on, type of road, level of visual clutter), the CEVMS DCZs on freeways had a greater setback from the road (133 ft for both CEVMS) than the standard billboards (10 and 35 ft). Signs with greater setback from the road would in a sense move out of the forward view (road ahead) more quickly than signs that are closer to the road. The CEVMS and standard billboards on the arterials were more closely matched with respect to setback from the road (12 and 43 ft for CEVMS and 20 and 40 ft for standard billboards).

The differences in setback from the road for CEVMS and standard billboards may also account for differences in dwell times to these two types of billboards. However, on arterials where the CEVMS and standard billboards were more closely matched there was only one long dwell time (greater than 2,000 ms) and it was to a standard billboard at night.

RICHMOND

The objectives of the second study were the same as those in the first study, and the design of the Richmond data collection effort was very similar to that employed in Reading. This study was conducted to replicate as closely as possible the design of Reading in a different driving environment. The independent variables included the type of DCZ (CEVMS, standard billboard, or no off-premise advertising), time of day (day or night) and road type (freeway or arterial). As with Reading, the time of day was a between-subjects variable and the other variables were within subjects.

METHOD

Selection of DCZ Limits

Selection of the DCZ limits procedure was the same as that employed in Reading.

Advertising Type

Three DCZ types (similar to those used in Reading) were used in Richmond:

- **CEVMS.** DCZs contained one target CEVMS.
- **Standard billboard.** DCZs contained one target standard billboard.
- **Control conditions.** DCZs did not contain any off-premise advertising.

There were an equal number of CEVMS and standard billboard DCZs on freeways and arterials. Also, there two DCZ that did not contain off-premise advertising with one located on a freeway and the other on an arterial.

Table 7 is an inventory of the target employed in this second study.

Table 7. Inventory of target billboards in Richmond with relevant parameters.

DCZ	*Advertising Type*	*Copy Dimensions (ft)*	*Side of Road*	*Setback from Road (ft)*	*Other Standard Billboards*	*Approach Length (ft)*	*Roadway Type*
5	CONTROL	N/A	N/A	N/A	N/A	710	Arterial
3	CONTROL	N/A	N/A	N/A	N/A	845	Freeway
9	CEVMS	14'0" x 28'0"	L	37	0	696	Arterial
13	CEVMS	14'0" x 28'0"	R	37	0	602	Arterial
2	CEVMS	12'5" x 40'0"	R	91	0	297	Freeway
8	CEVMS	11'0 x 23'0"	L	71	0	321	Freeway
10	Standard	14'0" x 48'0"	L	79	1	857	Arterial
12	Standard	10'6" x 45'3"	R	79	2	651	Arterial
1	Standard	14'0" x 48'0"	L	87	0	997	Freeway
7	Standard	14'0" x 48'0"	R	88	0	816	Freeway

* *N/A indicates that there were no off-premise advertising in these areas and these values are undefined.*

Figure 25 through figure 30 below represent various pairings of DCZ type and road type. Target off-premise billboards are indicated by red rectangles.

Figure 25. Example of a CEVMS DCZ on a freeway.

Figure 26. Example of CEVMS DCZ an arterial.

Figure 27. Example of a standard billboard DCZ on a freeway.

Figure 28. Example of a standard billboard DCZ on an arterial.

Figure 29. Example of a control DCZ on a freeway.

Figure 30. Example of a control DCZ on an arterial.

Photometric Measurement of Signs

The methods and procedures for the photometric measures were the same as for Reading.

Visual Complexity

The methods and procedures for visual complexity measurement were the same as for Reading.

Participants

A total of 41 participants were recruited for the study. Of these, 6 participants did not complete data collection because of an inability to properly calibrate with the eye tracking system, and 11 were excluded because of equipment failures. A total of 24 participants (13 male, M = 28 years; 11 female, M = 25 years) successfully completed the drive. Fourteen people participated during the day and 10 participated at night.

Procedures

Research participants were recruited locally by means of visits to public libraries, student unions, community centers, etc. A large number of the participants were recruited from a nearby university, resulting in a lower mean participant age than in Reading.

Participant Testing

Two people participated each day. One person participated during the day beginning at approximately 12:45 p.m. The second participated at night beginning at around 7:00 p.m. Data collection ran from November 20, 2009, through April 23, 2010. There were several long gaps in the data collection schedule due to holidays and inclement weather.

Pre-Data Collection Activities

This was the same as in Reading.

Practice Drive

Except for location, this was the same as in Reading.

Data Collection

The procedure was much the same as in Reading. On average, each test route required approximately 30 to 35 minutes to complete. As in Reading, the routes included a variety of freeway and arterial driving segments. One route was 15 miles long and contained two target CEVMS, two target standard billboards, and two DCZs with no off-premise advertising. The second route was 20 miles long and had two target CEVMS and two target standard billboards.

The data collection drives in this second study were longer than those in Reading. The eye tracking system had problems dealing with the large files that resulted. To mitigate this technical difficulty, participants were asked to pull over in a safe location during the middle of each data collection drive so that new data files could be initiated.

Upon completion of the data collection, the participant was instructed to return to the designated meeting location for debriefing.

Debriefing

This was the same as in Reading.

DATA REDUCTION

Eye Tracking Measures

The approach and procedures were the same as used in Reading.

Other Measures

The approach and procedures were the same as used in Reading.

RESULTS

Photometric Measurement of Signs

The photometric measurements were performed using the same equipment and procedures that were employed in Reading with a few minor changes. Photometric measurements were taken during the day and at night. Measurements of the standard billboards were taken at an average distance of 284 ft, with maximum and minimum distances of 570 ft and 43 ft, respectively. The average distance of measurements for the CEVMS was 479 ft, with maximum and minimum distances of 972 ft and 220 ft, respectively. Again, the distances employed were significantly affected by the requirement to find a safe location on the road from which to take the measurements.

Luminance

The mean luminance of CEVMS and standard billboards, during daytime and nighttime are shown below in table 8. The results here are similar to those for Reading.

Contrast

The daytime and nighttime Weber contrast ratios for both types of billboards are shown in table 8. During the day, the contrast ratios of both CEVMS and standard billboards were close to zero (the surroundings were about equal in brightness to the signs). At night, the CEVMS and standard billboards had positive contrast ratios. Similar to Reading, the CEVMS showed a higher contrast ratio than the standard billboards at night.

Table 8. Summary of luminance (cd/m^2) and contrast (Weber ratio) measurements.

	Luminance (cd/m^2)		*Contrast*	
Day	Mean	St. Dev.	Mean	St. Dev.
CEVMS	2134	798.70	-0.20	0.53
Standard Billboard	3063	2730.92	0.03	0.32
Night				
CEVMS	56.44	16.61	69.70	59.18
Standard Billboard	8.00	5.10	6.56	3.99

Visual Complexity

As with Reading, the feature congestion measure was used to estimate the level of visual complexity/clutter in the DCZs. The analysis procedures were the same as for Reading.

Figure 31 shows the mean feature congestion measures for each of the advertising types (standard errors are included in the figure). Unlike the results for Reading, the selected off-premise advertising DCZs for Richmond differed in terms of mean feature congestion; $F(3, 36) = 3.95$, $p = 0.016$. Follow up t-tests with an alpha of 0.05 showed that the CEVMS DCZs on arterials had significantly lower feature congestion than all of the other off-premise advertising conditions. None of the remaining DCZs with off-premise advertising differed from each other. The selection of DCZs for the conditions with off-premise advertising took into account the type of road, the side of the road the target billboard was placed, and the perceived level of visual clutter. Based on the feature congestion measure, these results indicated that the conditions with off-premise advertising were not equated with respect to level of visual clutter.

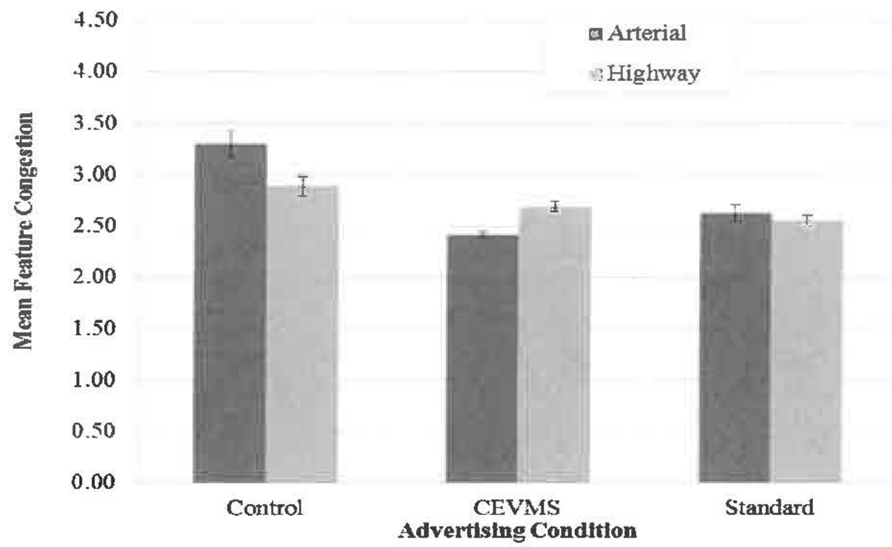


Figure 31. Mean feature congestion as a function of advertising condition and road type.

Effects of Billboards on Gazes to the Road Ahead

As was done for the data from Reading, GEE were used to analyze the probability of a participant gazing at the road ahead. A logistic regression model for repeated measures was generated by using a binomial response distribution and Logit link function. The resultant value was the probability of a participant gazing at the road ahead (as previously defined).

Time of day (day or night), road type (freeway or arterial), advertising type (CEVMS, standard billboard, or control), and all corresponding second-order interactions were explanatory variables in the logistic regression model. The interaction of advertising type by road type was statistically significant, $\chi^2(2) = 14.19$, $p < 0.001$. Table 9 shows the corresponding probability of gazing at the road ahead as a function of advertising condition and road type.

Table 9. The probability of gazing at the road ahead as a function of advertising condition and road type.

Advertising Condition	*Arterial*	*Freeway*
Control	0.78	0.92
CEVMS	0.76	0.82
Standard	0.81	0.85

Follow-up analyses for the interaction used Tukey-Kramer adjustments with an alpha level of 0.05. The freeway control had the greatest probability of gazing at the road ahead (M = 0.92). This probability differed significantly from the remaining five probabilities. On arterials, there were no significant differences among the probabilities of gazing at the road ahead among the three advertising conditions. On freeways, there was no significant difference between the probability associated with CEVMS DCZs and the probability associated with standard billboard DCZs.

Additional descriptive statistics were computed for the three advertising types to determine the probability of gazing at the ROIs that were defined in the panoramic scene. As was done with the data from Reading, some of the ROIs were combined for ease of analysis. Table 10 presents the probability of gazing at the different ROIs.

Table 10. Probability of gazing at ROIs for the three advertising conditions on arterials and freeways.

Road Type	*ROI*	*CEVMS*	*Standard Billboard*	*Control*
Arterial	*CEVMS*	0.06	N/A	N/A
	Left Side of Vehicle	0.03	0.05	0.04
	Road ahead	0.76	0.81	0.78
	Right Side of Vehicle	0.07	0.06	0.09
	Standard Billboard	N/A	0.02	N/A
	Participant Vehicle	0.07	0.06	0.09
Freeway	*CEVMS*	0.05	N/A	N/A
	Left Side of Vehicle	0.03	0.01	0.01
	Road ahead	0.82	0.85	0.92
	Right Side of Vehicle	0.04	0.04	0.03
	Standard Billboard	N/A	0.04	N/A
	Participant Vehicle	0.06	0.06	0.05

The probability of gazing away from the forward roadway ranged from 0.08 to 0.24. In particular, the probability of gazing toward a CEVMS was slightly greater on arterials (M = 0.06) than on freeways (M = 0.05). In contrast, the probability of gazing toward a standard billboard was greater on freeways (M = 0.04) than on arterials (M = 0.02). In both situations, the probability of gazing at the road ahead was greatest on freeways.

Fixations to CEVMS and Standard Billboards

About 2.5 percent of the fixations were to CEVMS. The mean fixation duration to a CEVMS was 371 ms and the maximum fixation duration was 1,335 ms. Figure 32 shows the distribution of fixation durations to CEVMS during the day and at night. In the daytime, the mean fixation duration to a CEVMS was 440 ms and at night it was 333 ms. Approximately 1.5 percent of the fixations were to standard billboards. The mean fixation duration to standard billboards was 318 ms and the maximum fixation duration was 801 ms. Figure 33 shows the distribution of fixation durations for standard billboards. The mean fixation duration to a standard billboard was 313 ms and 325 ms during the day and night, respectively. For comparison purposes, figure 34 shows the distribution of fixation durations to the road ahead during the day and night. In the daytime, the mean fixation duration to the road ahead was 378 ms and at night it was 358 ms.

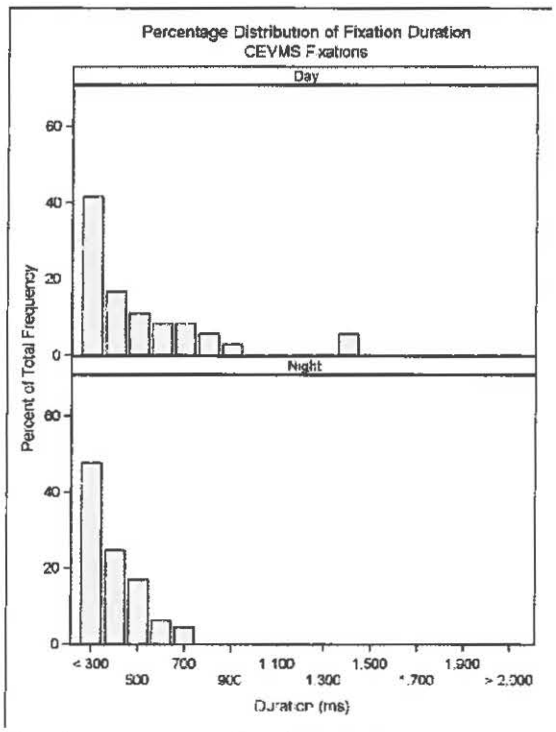


Figure 32. Fixation duration for CEVMS in the day and at night.

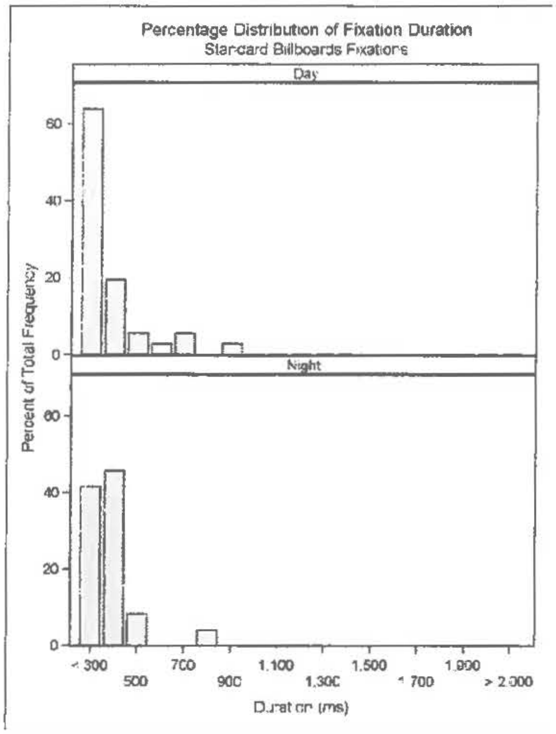


Figure 33. Fixation duration for standard billboards in the day and at night.

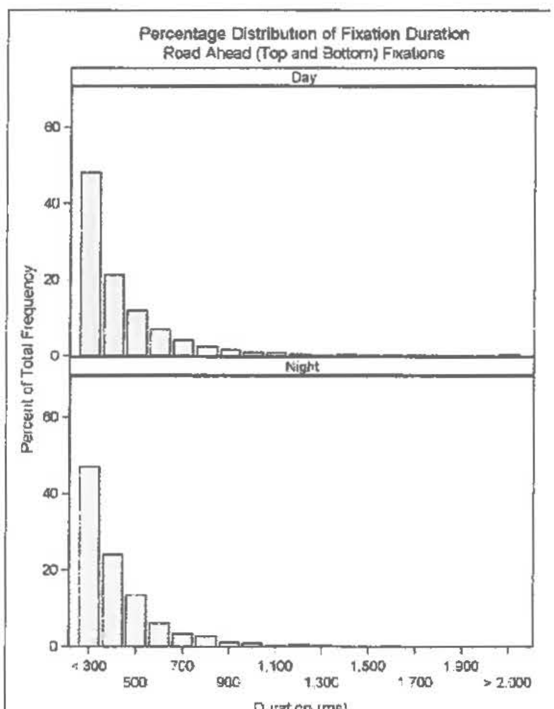


Figure 34. Fixation duration for the road ahead in the day and at night.

As was done with the data for Reading, the record of fixations was examined to determine dwell times to CEVMS and standard billboards. There were a total of 21 separate dwell times to CEVMS with a mean of 2.86 sequential fixations (minimum of 2 fixations and maximum of 6 fixations). The 21 dwell times came from 12 different participants and four different CEVMS. The mean dwell time duration to the CEVMS was 1,039 ms (minimum of 500 ms and maximum of 2,720 ms). There was one dwell time greater than 2,000 ms to CEVMS. To the standard billboards there were 13 separate dwell times with a mean of 2.31 sequential fixations (minimum of 2 fixations and maximum of 3 fixations). The 13 dwell times came from 11 different participants and four different standard billboards. The mean dwell time duration to the standard billboards was 687 ms (minimum of 450 ms and maximum of 1,152 ms). There were no dwell times greater than 2,000 ms to standard billboards.

In some cases several dwell times came from the same participant. To compute a statistic on the difference between dwell times for CEVMS and standard billboards, average dwell times were computed per participant for the CEVMS and standard billboard conditions. These average values were used in a *t*-test assuming unequal variances. The difference in average dwell time between CEVMS (M = 1,096 ms) and standard billboards (M= 674 ms) was statistically significant, $t(14) = 2.23, p = .043$.

Figure 35 through figure 37 show heat maps for the dwell-time durations to the CEVMS that were greater than 2,000 ms. The DCZ was on a freeway during the daytime. The CEVMS is located on the left side of the road (indicated by an orange rectangle). There were three fixations to this billboard, and the single fixations were between 651 ms and 1,335 ms. The dwell time for this billboard was 2,270 ms. Figure 35 shows the first fixation toward the CEVMS. There are no vehicles near the participant in his/her respective travel lane or adjacent lanes. In this situation, the billboard is relatively close to the road ahead ROI. Figure 36 shows a heat map later in the DCZ where the driver continues to look at the CEVMS. The heat map does not overlay the CEVMS in the picture since the heat map has integrated over time where the driver was gazing. The CEVMS has moved out of the area because of the vehicle moving down the road. However, visual inspection of the video and eye tracking statistics showed that the driver was fixating on the CEVMS. Figure 37 shows the end of the sequential fixations to the CEVMS. The driver returns to gaze directly in front of the vehicle. Once the CEVMS was out of the forward field of view, the driver quit looking at the billboard.

Figure 35. Heat map for first fixation to CEVMS with long dwell time.

Figure 36. Heat map for later fixations to CEVMS with long dwell time.

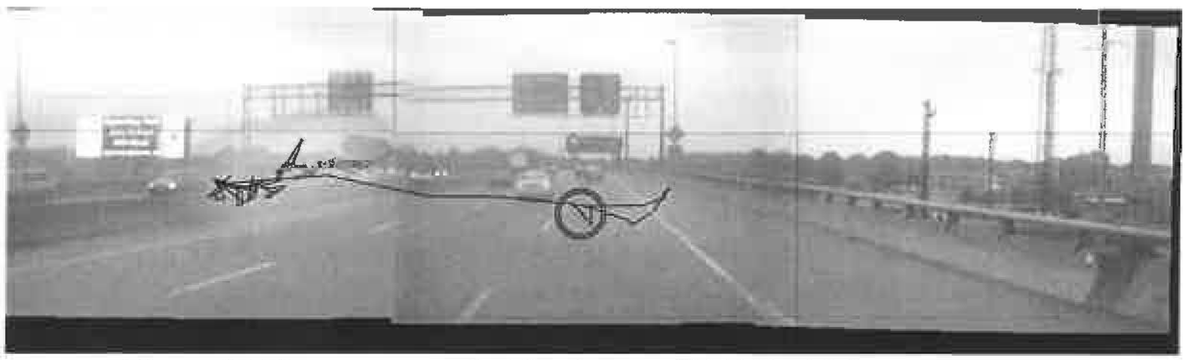


Figure 37. Heat map at end of fixations to CEVMS with long dwell time.

Comparison of Gazes to CEVMS and Standard Billboards

As was done for the data from Reading, GEE were used to analyze whether a participant gazed more toward CEVMS than toward standard billboards, given that the participant was looking at off-premise advertising. Recall that a sample probability greater than 0.5 indicated that participants gazed more toward CEVMS than standard billboards when the participants gazed at off-premise advertising. In contrast, if the sample probability was less than 0.5, participants showed a preference to gaze more toward standard billboards than CEVMS when directing visual attention to off-premise advertising.

Time of day (i.e., day or night), road type (i.e., freeway or arterial), and the corresponding interaction were explanatory variables in the logistic regression model. Time of day had a significant effect on participant gazes toward off-premise advertising, $\chi^2(1) = 4.46, p = 0.035$. Participants showed a preference to gaze more toward CEVMS than toward standard billboards during both times of day. During the day the preference was only slight (M = 0.52), but at night the preference was more pronounced (M = 0.71). Road type was also a significant predictor of where participants directed their gazes at off-premise advertising, $\chi^2(1) = 3.96, p = 0.047$. Participants gazed more toward CEVMS than toward standard billboards while driving on both types of roadways. However, driving on freeways yielded a slight preference for CEVMS over standard billboards (M = 0.55), but driving on arterials resulted in a larger preference in favor of CEVMS (M = 0.68).

Observation of Driver Behavior

No near misses or driver errors occurred.

Level of Service

Table 11 shows the level of service as a function of advertising type, type of road, and time of day. As expected, there was less congestion during the nighttime runs than in the daytime. In general, there was traffic during the data collection runs; however, the eye tracking data were recorded while the vehicles were in motion.

Table 11. Estimated level of service as a function of advertising condition, road type, and time of day.

	Arterial		Freeway	
	Day	Night	Day	Night
Control	B	A	C	B
CEVMS	B	A	B	A
Standard	C	A	C	C

DISCUSSION OF RICHMOND RESULTS

Overall the probability of looking at the forward roadway was high across all conditions and consistent with the findings from Reading and previous related research.[11,9,12] In this second study the CEVMS and standard billboard conditions did not differ from each other. For the DCZs on arterials there were no significant differences among the control, CEVMS, and standard billboard conditions. On the other hand, while the CEVMS and standard billboard conditions on the freeways did not differ from each other, they were significantly different from their respective control conditions. The control condition on the freeway principally had trees along the sides of the road and the signs that were present were freeway signs located in the road ahead ROI.

Measures such as feature congestion rated the three DCZs on freeways as not being statistically different from each other. These types of measures have been useful in predicting visual search and the effects of visual salience in laboratory tasks.[34] Models of visual salience may predict that, at least during the daytime, trees on the side of the road may be visually salient objects that would attract a driver's attention.[47] However, it appears that in the present study, participants principally kept their eyes on the road ahead.

The mean fixations to CEVMS, standard billboards, and the road ahead were found to be similar in magnitude with no long fixations. Examination of dwell times showed that there was one long dwell time for a CEVMS greater than 2,000 ms and it occurred in the daytime on a sign located on the left side of the road on a freeway DCZ. Furthermore, when averaging among participants the mean dwell time for CEVMS was significantly longer than to standard billboards, but still under 2,000 ms. For the dwell time greater than 2,000 ms, examination of the scene camera video and eye tracking heat maps showed that the driver was initially looking toward the forward roadway and made a first fixation to the sign. Three fixations were made to the sign and then the driver started looking back to the road ahead as the sign moved out of the forward field of view. On the video there were no vehicles near the subject driver's own lane or in adjacent lanes.

Only the central 2 degrees of vision, foveal vision, provide resolution sharp enough for reading or recognizing fine detail.[57] However, useful information for reading can be extracted from parafoveal vision, which encompasses the central 10 degrees of vision.[57] More recent research on scene gist recognition[3] has shown that peripheral vision (beyond parafoveal vision) is more useful than central vision for recognizing the gist of a scene.[58] Scene gist recognition is a critically important early stage of scene perception, and influences more complex cognitive processes such as directing attention within a scene and facilitating object recognition, both of which are important in obtaining information while driving.

The results of this study do show one duration of eyes off the forward roadway greater than 2,000 ms, the duration at which Klauer et al. observed near-crash/crash risk at more than twice those of normal, baseline driving.[14,53] When looking at the tails of the fixation distributions, few fixations were greater than 1,000 ms, with the longest fixation being equal to 1,335 ms.[53,54] The one long dwell time on a CEVMS that was observed was a rare event in this study, and review of the video and eye tracking data suggests that the driver was effectively managing acquisition of visual information while driving and fixated on the advertising. However, additional work needs to be done to derive criteria for gazing or fixating away from the forward road view where the road scene is still visible in peripheral vision.

The results showed that drivers are more likely to look at CEVMS than standard billboards during the nighttime across the conditions tested (at night the average probability of gazing at CEVMS was M= 0.71). CEVMS do have greater luminance than standard billboards at night and also have higher contrast. The CEVMS have the capability of being lit up so that they would appear as very bright signs to drivers (for example, up to about10,000 cd/m^2 for a white square on the sign.). However, our measurements of these signs showed an average luminance of about 56 cd/m^2. These signs would be conspicuous in a nighttime driving environment but significantly less so than other light sources such as vehicle headlights. Drivers were also more likely to look at CEVMS than standard billboards on both arterials and freeways, with a higher probability of gazes on arterials.

In this second study, CEVMS and standard billboards were more nearly equated with respect to setback from the road. Gazes to the road ahead were not significantly different between CEVMS and standard billboard DCZs across conditions and the proportion of gazes to the road ahead were consistent with previous research. One long dwell time for a CEVMS was observed in this study; however, it occurred in the daytime where the luminance and contrast (affecting the perceived brightness) of these signs are similar to those for standard billboards.

[3] "Scene gist recognition" refers to the element of human cognition that enables us to determine the meaning of a scene and categorize it by type (e.g., a beach, an office) almost immediately upon seeing it.

GENERAL DISCUSSION

This study was conducted to investigate the effect of CEVMS on driver visual behavior in a roadway driving environment. An instrumented vehicle with an eye tracking system was used. Roads containing CEVMS, standard billboards, and control areas with no off-premise advertising were selected. The CEVMS and standard billboards were measured with respect to luminance, location, size, and other relevant variables to characterize these visual stimuli. Unlike previous studies on digital billboards, the present study examined CEVMS as deployed in two United States cities and did not contain dynamic video or other dynamic elements. The CEVMS changed content approximately every 8 to 10 seconds, consistent within the limits provided by FHWA guidance.[2] In addition, the eye tracking system used had nearly a 2-degree level of resolution that provided significantly more accuracy in determining what objects the drivers were gazing or fixating on as compared to some previous field studies examining CEVMS.

CONCLUSIONS

Do CEVMS attract drivers' attention away from the forward roadway and other driving relevant stimuli?

Overall, the probability of looking at the road ahead was high across all conditions. In Reading, the CEVMS condition had a lower proportion of gazes to the road ahead than the standard billboard condition on the freeways. Both of the off-premise advertising conditions had a lower proportion of gazes to the road ahead than the control condition on the freeway. The lower proportion of gazes to the road ahead can be attributed to the overall distribution of gazes away from the road ahead and not just to the CEVMS. On the other hand, for the arterials the CEVMS and standard billboard conditions did not differ from each other, but both had a lower proportion of gazes to the road ahead compared to the control. In Richmond there were no differences among the three advertising conditions on the arterials. However, for the freeways the CEVMS and standard billboard conditions did not differ from each other but had a lower proportion of gazes to the road ahead than the control.

The control conditions differed across studies. In Reading, the control condition on arterials showed 92 percent for gazing at the road ahead while on the freeway it was 86 percent. On the other hand, in Richmond the control condition for arterials was 78 percent and for the freeway it was 92 percent. The control conditions on the freeway differed across the two studies. In Reading there were businesses off to the side of the road; whereas in Richmond the sides of the road were mostly covered with trees. The control conditions on the arterials also differed across cities in that both contained businesses and on-premise advertising; however, in Reading arterials had four lanes and in Richmond arterials had six lanes. The reason for these differences across cities was that these control conditions were selected to match the other conditions (CEVMS and standard billboards) that the drivers would experience in the two respective cities. Also, the selection of DCZs was obviously constrained by what was available on the ground in these cities.

The results for the off-premise advertising conditions are consistent with Lee et al., who observed that 76 percent of drivers' time was spent looking at the road ahead in the CEVMS scenario and 75 percent in the standard billboard scenario.[9] However, it should be kept in mind that drivers did gaze away from the road ahead even when no off-premise advertising was present and that the presence of clutter or salient visual stimuli did not necessarily control where drivers gazed.

Do glances to CEVMS occur that would suggest a decrease in safety?

In DCZs containing CEVMS, about 2.5 percent of the fixations were to CEVMS (about 2.4 percent to standard billboards). The results for fixations are similar to those reported in other field data collection efforts that included advertising signs.[12,11,9,13] Fixations greater than 2,000 ms were not observed for CEVMS or standards billboards.

However, an analysis of dwell times to CEVMS showed a mean dwell time of 994 ms (maximum of 1,467 ms) for Reading and a mean of 1,039 ms (maximum of 2,270 ms) for Richmond. Statistical comparisons of average dwell times between CEVMS and standard billboards were not significant in Reading; however, in Richmond the average dwell times to CEVMS were significantly longer than to standard billboards, though below 2,000 ms. There was one dwell time greater than 2,000 ms to a CEVMS across the two cities. On the other hand, for standard billboards there were three long dwell times in Reading; there were no long dwell times to these billboards in Richmond. Review of the video data for these four long dwell times showed that the signs were not far from the forward view when participants were fixating. Therefore, the drivers still had access to information about what was in front of them through peripheral vision.

As the analyses of gazes to the road ahead showed, drivers distributed their gazes away from the road ahead even when there were no off-premise billboards present. Also, drivers gazed and fixated on off-premise signs even though they were generally irrelevant to the driving task. However, the results did not provide evidence indicating that CEVMS were associated with long glances away from the road that may reflect an increase in risk. When long dwell times occurred to CEVMS or standard billboards, the road ahead was still in the driver's field of view.

Do drivers look at CEVMS more than at standard billboards?

The drivers were generally more likely to gaze at CEVMS than at standard billboards. However, there was some variability between the two locations and between type of roadway (arterial or freeway). In Reading, the participants looked more often at CEVMS when on arterials, whereas they looked more often at standard billboards when on freeways. In Richmond, the drivers looked at CEVMS more than standard billboards no matter the type of road they were on, but as in Reading the preference for gazing at CEVMS was greater on arterials (68 percent on arterials and 55 percent on freeways). The slower speed on arterials and sign placement may present drivers with more opportunities to gaze at the signs.

In Richmond, the results showed that drivers gazed more at CEVMS than standard billboards at night; however, for Reading no effect for time of day was found. CEVMS do have higher luminance and contrast than standard billboards at night. The results showed mean luminance of about 56 cd/m^2 in the two cities where testing was conducted. These signs would appear clearly visible but not overly bright.

SUMMARY

The results of these studies are consistent with a wealth of research that has been conducted on vision in natural environments.[26,22,21] In the driving environment, gaze allocation is principally controlled by the requirements of the task. Consistent results were shown for the proportion of gazes to the road ahead for off-premise advertising conditions across the two cities. Average fixations were similar to CEVMS and standard billboards with no long single fixations evident for either condition. Across the two cities, four long dwell times were observed: one to a CEVMS on a freeway in the day, two to the same standard billboard on a freeway (once at night and once in the daytime), and one to a standard billboard on an arterial at night. Examination of the scene video and eye tracking data indicated that these long dwell times occurred when the billboards were close to the forward field of view where peripheral vision could still be used to gather visual information on the forward roadway.

The present data suggest that the drivers in this study directed the majority of their visual attention to areas of the roadway that were relevant to the task at hand (i.e., the driving task). Furthermore, it is possible, and likely, that in the time that the drivers looked away from the forward roadway, they may have elected to glance at other objects in the surrounding environment (in the absence of billboards) that were not relevant to the driving task. When billboards were present, the drivers in this study sometimes looked at them, but not such that overall attention to the forward roadway decreased.

LIMITATIONS OF THE RESEARCH

In this study the participants drove a research vehicle with two experimenters on board. The participants were provided with audio turn-by-turn directions and consequently did not have a taxing navigation task to perform. The participants were instructed to drive as they normally would. However, the presence of researchers in the vehicle and the nature of the driving task do limit the degree to which one may generalize the current results to other driving situations. This is a general limitation of instrumented vehicle research.

The two cities employed in the study appeared to follow common practices with respect to the content change frequency (every 8 to 10 seconds) and the brightness of the CEVMS. The current results would not generalize to situations where these guidelines are not being followed.

Participant recruiting was done through libraries, community centers and at a university. This recruiting procedure resulted in a participant demographic distribution that may not be representative of the general driving population.

The study employed a head-free eye tracking device to increase the realism of the driving situation (no head-mounted gear). However, the eye tracker had a sampling rate of 60 Hz, which made determining saccades problematic. The eye tracker and analyses software employed in this effort represents a significant improvement in technology over previous similar efforts in this area.

The study focused on objects that were 1,000 feet or less from the drivers. This was dictated by the accuracy of the eye tracking system and the ability to resolve objects for data reduction. In addition, the geometry of the roadway precluded the consideration of objects at great distances.

The study was performed on actual roadways, and this limited the control of the visual scenes except via the route selection process. In an ideal case, one would have had roadways with CEVMS, standard billboards, and no off-premise advertising and in which the context surrounding digital and standard billboards did not differ. This was not the case in this study, although such an exclusive environment would be inconsistent with the experience of most drivers. This presents issues with the interpretation of the specific contributions made by billboards and the environment to the driver's behavior.

Sign content was not investigated (or controlled) in the present study, but may be an important factor to consider in future studies that investigate the distraction potential of advertising signs. Investigations about the effect of content could potentially be performed in driving simulators where this variable could be systematically controlled and manipulated.

REFERENCES

1. National Highway Traffic Safety Administration. Policy Statement. [Available online at http://www.nhtsa.gov/Driving+Safety/Distracted+Driving/ci.Policy+Statement+and+Compiled+FAQs+on+Distracted+Driving.print.] Accessed 7/27/2012.
2. Shepherd, G. M., 2007: Guidance on Off-Premise Changeable Message Signs. http://www.fhwa.dot.gov/realestate/offprmsgsnguid.htm.
3. Scenic America. Position Paper Regarding the Propriety of Permitting Digital Billboards on Interstate and Federal-Aid Highways under the Highway Beautification Act. 2010.
4. Molino, J. A., J. Wachtel, J. E. Farbry, M. B. Hermosillo, and T. M. Granda. . The Effects of Commercial Electronic Variable Message Signs (Cevms) on Driver Attention and Distraction: An Update., FHWA-HRT-09-018. Federal Highway Administration, 2009.
5. Farbry, J., Wochinger, K., Shafer, T., Owens, N, & Nedzesky, A. Research Review of Potential Safety Effects of Electronic Billboards on Driver Attention and Distraction. Federal Highway Administration. Washington, DC, 2001.
6. Tantala, M. W., and A. M. Tantala. A Study of the Relationship between Digital Billboards and Traffic Safety in Henrico County and Richmond, Virginia. The Foundation for Outdoor Advertising Research and Education (FOARE), 2010.
7. Tantala, M. W., and A. M. Tantala. An Examination of the Relationship between Digital Billboards and Traffic Safety in Reading, Pennsylvania Using Empirical Bayes Analyses. *Moving Toward Zero 2100. ITE Technical Conference and Exhibit*, Buena Vista, FL, Institute of Transportation Engineers, 2011.
8. Elvik, R. The Predictive Validity of Empirical Bayes Estimates of Road Safety. *Accident Analysis & Prevention*, **40**, 2008, 1964-1969.
9. Lee, S. E., McElheny, M.J., & Gibbons, R. . Driving Performance and Digital Billboards. Report prepared for Foundation for Outdoor Advertising Research and Education. Virginia Tech Transportation Institute., 2007.
10. Society of Automotive Engineers. Definitions and Experimental Measures Related to the Specification of Driver Visual Behavior Using Video Based Techniques. 2000.
11. Beijer, D., A. Smiley, and M. Eizenman. Observed Driver Glance Behavior at Roadside Advertising Signs. *Transportation Research Record: Journal of the Transportation Research Board,, **No. 1899***, 2004, 96-103.
12. Smiley, A., T. Smahel, and M. Eizenman. Impact of Video Advertising on Driver Fixation Patters. *Transportation Research Record: Journal of the Transportation Research Board,*, **No. 1899**, 2004, 76-83.
13. Kettwich, C., K. Klinger, and U. Lemmer. Do Advertisements at the Roadside Distract the Driver? *Optical Sensors 2008*, San Diego, CA, SPIE, 2008.
14. Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J.D., & Ramsey, D.J. The Impact of Driver Inattention on near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data, DOT HS 810 594. National Highway Traffic Safety Administration, 2006.
15. Chattington, M., N. Reed, D. Basacik, A. Flint, and A. Parkes. Investigating Driver Distraction: The Effects of Video and Static Advertising, PPR409. Transport Research Laboratory, 2009.

16. Kettwich, C., K. Klinger, and U. Lemmer, 2008: Do Advertisements at the Roadside Distract the Driver? *Optical Sensors 2008*, F. Berghmans, A. G. Mignani, A. Cutolo, P. P. Moyrueis, and T. P. Pearsall, Eds., SPIE.
17. Cole, B. L., and P. K. Hughes. A Field Trial of Attention and Search Conspicuity. *Human Factors*, **26**, 1984, 299-313.
18. Ruz, M., and J. Lupiáñez. A Review of Attentional Capture: On Its Automaticity and Sensitivity to Endogenous Control. *Psicológica*, **23**, 2002, 283-309.
19. Wachtel, J. Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs. The Veridian Group, Inc, 2009.
20. Theeuwes, J., and R. Burger. Attentional Control During Visual Search: The Effect of Irrelevant Singletons. *Journal of Experimental Psychology: Human Perception and Performance*, **24**, 1998, 1342-1353.
21. Tatler, B. W., M. M. Hayhoe, M. F. Land, and D. H. Ballard. Eye Guidance in Natural Vision: Reinterpreting Salience. *Journal of Vision*, **11**, 2011, 1-23.
22. Land, M. F. Vision, Eye Movements, and Natural Behavior. *Visual Neuroscience*, **26**, 2009, 51-62.
23. Eckstein, M. P. Visual Search: A Retrospective. *Journal of Vision*, **11**, 2011, 1-36.
24. Henderson, J., G. Malcolm, and C. Schandl. Searching in the Dark: Cognitive Relevance Drives Attention in Real-World Scenes. *Psychonomic Bulletin & Review*, **16**, 2009, 850-856.
25. Henderson, J. M., J. R. Brockmole, M. S. Castelhano, and M. Mack, 2007: Visual Saliency Does Not Account for Eye Movements During Visual Search in Real-World Scenes. *Eye Movements: A Window on Mind and Brain*, R. P. G. v. Gompel, M. H. Fischer, W. S. Murray, and R. L. Hill, Eds., Elsevier, 537-562.
26. Land, M. F. Eye Movements and the Control of Actions in Everyday Life. *Progress in Retinal and Eye Research*, **25**, 2006, 296-324.
27. Hayhoe, M., and D. Ballard. Eye Movements in Natural Behavior. *Trends in Cognitive Sciences*, **9**, 2005, 188-194.
28. Jovancevic-Misic, J., and M. Hayhoe. Adaptive Gaze Control in Natural Environments. *The Journal of Neuroscience*, **29**, 2009, 6234-6238.
29. Shinoda, H., M. M. Hayhoe, and A. Shrivastava. What Controls Attention in Natural Environments? *Vision Research*, **41**, 2001, 3535-3545.
30. SmartEye. Smarteye. [Available online at http://www.smarteye.se/.] Accessed June 22, 2012.
31. Whittle, P., Ed., 1994: *The Psychophysics of Contrast Brightness*. Lawrence Erlbaum Associates.
32. Regan, M. A., K. L. Young, J. D. Lee, and C. P. Gordon, 2009: Sources of Driver Distraction. *Driver Distraction: Theory, Effects, and Mitigation.*, M. A. Regan, J. D. Lee, and K. L. Young, Eds., CRC Press, Taylor & Francis Group.
33. Horberry, T., & Edquist, J., 2009: Distractions Outside the Vehicle. *Driver Distraction: Theory, Effects, and Mitigation.*, M. A. Regan, Lee, J.D., & Young, K.L., Ed., CRC Press, Taylor & Francis Group.
34. Rosenholtz, R., Y. Li, and L. Nakano. Measuring Visual Clutter. *J Vis*, **7**, 2007, 17 11-22.
35. Bravo, M. J., and H. Farid. A Scale Invariant Measure of Clutter. *Journal of Vision*, **8**, 2008, 1-9.

36. EyesDx. Multiple-Analysis of Psychophysical and Performance Signals (Mapps) [Available online at http://www.eyesdx.com/.] Accessed June 22, 2012.
37. Recarte, M. A., and L. M. Nunes. Effects of Verbal and Spatial-Imagery Tasks on Eye Fixations While Driving. *Journal of Experimental Psychology: Applied*, **6**, 2000, 31-43.
38. Manor, B. R., and E. Gordon. Defining the Temporal Threshold for Ocular Fixation in Free-Viewing Visuocognitive Tasks. *Journal of Neuroscience Methods*, **128**, 2003, 85-93.
39. Ahlstrom, C., K. Kircher, and A. Kircher. Considerations When Calculating Percent Road Centre from Eye Movement Data in Driver Distraction Monitoring. *Proceedings of the Fifth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, 2009, 132-139.
40. Agresti, A., 2002: Analyzing Repeated Categorical Response Data. *Categorical Data Analysis, 2nd Edition*, D. J. Balding, Ed., John Wiley & Sons, Inc.
41. Stokes, M. E., C. S. Davis, and G. G. Koch. *Categorical Data Analysis Using the Sas System (2nd Ed.).* SAS Institute, Inc., Cary, NC, 2000.
42. Molenbergs, G., and G. Verbeke. Likelihood Ratio, Score, and Wald Tests in a Constrained Parameter Space. *The American Statistican*, **61**, 2007, 22-27.
43. ISO, 2002: Road Vehicles — Measurement of Driver Visual Behaviour with Respect to Transport Information and Control Systems —Part 1: Definitions and Parameters. ISO.
44. ISO, 2001: Road Vehicles — Measurement of Driver Visual Behaviour with Respect to Transport Information and Control Systems — Part 2: Equipment and Procedures. ISO.
45. *Highway Capacity Manual.* Transportation Research Board, Washington, DC, 2000.
46. Itti, L., and C. Koch. A Saliency-Based Search Mechanism for Overt and Covert Shifts of Visual Attention. *Vision Research*, **40**, 2000, 1489-1506.
47. Walther, D., and C. Koch. Modeling Attention to Salient Proto-Objects. *Neural Networks*, **19**, 2006, 1395-1407.
48. Itti, L., C. Koch, and E. Niebur. A Model of Saliency-Based Visual Attention for Rapid Scene Analysis. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, **20**, 1998, 1254-1259.
49. Walther, D. B. Saliency Toolbox. [Available online at http://www.saliencytoolbox.net/index.html.] Accessed 6/27/2012.
50. Land, M. F. Predictable Eye-Head Coordination During Driving. *Nature*, **359**, 1992, 318-320.
51. Balas, B., L. Nakano, and R. Rosenholtz. A Summary-Statistic Representation in Peripheral Vision Explains Visual Crowding. *Journal of Vision*, **9**, 2009, 1-18.
52. Levi, D. M. Crowding--an Essential Bottleneck for Object Recognition: A Mini-Review. *Vision Research*, **48**, 2008, 635-654.
53. Horrey, W. J., and C. D. Wickens. In-Vehicle Glance Duration: Distributions,Tails, and Model of Crash Risk. *Transportation Research Record*, **2018**, 2007, 22-28.
54. Wierwille, W. W., 1993: Visual and Manual Demands of in-Car Controls and Displays. *Automotive Ergonomics*, B. Peacock, and W. Karwowsk, Eds., Taylor and Francis, 299-320.
55. Strasburger, H., I. Rentschler, and M. Jüttner. Peripheral Vision and Pattern Recognition: A Review. *Journal of Vision*, **11**, 2011, 1-82.

56. Reimer, B. Impact of Cognitive Task Complexity on Drivers' Visual Tunneling. *Transportation Research Record: Journal of the Transportation Research Board*, **No. 2138**, 2009, 13–19.
57. Rayner, K., A. W. Inhoff, R. E. Morrison, M. L. Slowiaczek, and J. H. Bertera. Masking of Foveal and Parafoveal Vision During Eye Fixations in Reading. *Journal of Experimental Psychology: Human Perception and Performance*, **7**, 1981, 167-179.
58. Larson, A. M., and L. C. Loschky. The Contributions of Central Versus Peripheral Vision to Scene Gist Recognition. *Journal of Vision*, **9**, 2009, 1-16.