Trip Generation at Virginia Agritourism Land Uses

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16. Abstract:

When new agritourism land uses are initially proposed, a lack of data on how many vehicle trips these uses tend to create (known as trip generation) means that there is limited guidance available for transportation planners and engineers to make appropriate and sound recommendations regarding entrances and other traffic improvements. Agritourism land uses can include farm wineries, breweries, distilleries, orchards allowing visitors to pick fruits and vegetables, and farm stands and markets. This study reviewed existing information about agritourism trip generation rates and conducted data collection and analysis with regard to these rates at five winery and cidery sites in Virginia. In Virginia, localities have the ability, albeit limited, to regulate special events held at agritourism sites, so this study looked at non-event trip volumes.

Engineers and transportation planners typically use trip generation data from the Institute of Transportation Engineers' Trip Generation Manual to determine entrance categories and to recommend street improvements and strategies for safety or capacity. The manual includes trip rates for several uses that could be considered related but that do not exactly represent the range or character of agritourism uses, with the possible exception of breweries serving a full menu approximating the manual's definition of "quality restaurant." The data reported in the manual for most of these agritourism-related uses had a large degree of variability. Recent studies of trip generation at wineries, all from California, were also reviewed.

Data collected for the five Virginia sites had high variability, but certain independent variables had moderately high correlations with trips: (1) number of employees, (2) population within a 60-minute drive, (3) households within a 60-minute drive, and (4) square footage of tasting room. Although based on a small sample size, the results suggest that established retail wineries/cideries are likely to exceed the Virginia Department of Transportation's 50-trips-per-day maximum threshold for a "low volume commercial entrance," falling instead into the "moderate volume commercial entrance" or the "commercial entrance" category.

Based on the findings of this study, it appears that VDOT's practice of assuming low trip volumes for agritourism land uses may result in entrances that are undersized for the amount of traffic they carry. The "moderate volume commercial entrance" category may be appropriate for agritourism land uses in most cases. In addition, weekday peak hour volumes for the agritourism land use sites studied did not occur during the weekday peak hours of adjacent streets. Promising site-based variables for Virginia wineries include square footage of a tasting room and number of employees at peak season, and when no site-based variables are available other than location, Census-derived variables can provide some information. Additional research could clarify the findings of this study.

Recommendations for VDOT's Office of Land Use include (1) providing guidance to VDOT's transportation and land use directors indicating that retail-focused wineries can be assumed to generate well more than 50 vehicle trips per day at peak season and (2) investigating possible adjustments to the traffic volume thresholds for the "moderate volume commercial entrance" category.

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FINAL REPORT

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ABSTRACT

When new agritourism land uses are initially proposed, a lack of data on how many vehicle trips these uses tend to create (known as trip generation) means that there is limited guidance available for transportation planners and engineers to make appropriate and sound recommendations regarding entrances and other traffic improvements. Agritourism land uses can include farm wineries, breweries, distilleries, orchards allowing visitors to pick fruits and vegetables, and farm stands and markets. This study reviewed existing information about agritourism trip generation rates and conducted data collection and analysis with regard to these rates at five winery and cidery sites in Virginia. In Virginia, localities have the ability, albeit limited, to regulate special events held at agritourism sites, so this study looked at non-event trip volumes.

Engineers and transportation planners typically use trip generation data from the Institute of Transportation Engineers' *Trip Generation Manual* to determine entrance categories and to recommend street improvements and strategies for safety or capacity. The manual includes trip rates for several uses that could be considered related but that do not exactly represent the range or character of agritourism uses, with the possible exception of breweries serving a full menu approximating the manual's definition of "quality restaurant." The data reported in the manual for most of these agritourism-related uses had a large degree of variability. Recent studies of trip generation at wineries, all from California, were also reviewed.

Data collected for the five Virginia sites had high variability, but certain independent variables had moderately high correlations with trips: (1) number of employees, (2) population within a 60-minute drive, (3) households within a 60-minute drive, and (4) square footage of tasting room. Although based on a small sample size, the results suggest that established retail wineries/cideries are likely to exceed the Virginia Department of Transportation's 50-trips-per-day maximum threshold for a "low volume commercial entrance," falling instead into the "moderate volume commercial entrance" or the "commercial entrance" category.

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INTRODUCTION

Agritourism land uses, which can be broadly defined as farm wineries, breweries, distilleries, retail orchards, and farm stands and markets, comprise a growing economic activity in parts of Virginia. Depending on the type of enterprise, visitors can typically pick fruits or vegetables, purchase produce and related products, consume items on premises, and attend events. The Virginia Department of Transportation (VDOT) field offices wanted to understand trip generation for these land uses better, because predicted traffic volumes inform the VDOT processes of approving entrance permits and recommending street improvements. Such information helps planners in their attempts to ensure traffic safety and minimize congestion while ensuring that agritourism land uses are not unfairly burdened. This study was initiated to review existing information about agritourism trip rates and conduct additional information-gathering and analysis for Virginia sites to the extent feasible.

Some wineries host events frequently and rely on them for income, and some agritourism land uses called "event centers" exist solely for events. Because localities, rather than VDOT, can regulate event-related impacts for events that could affect the health, safety, or welfare of the public, this study focused on determining non-event daily trip volumes. VDOT can work with localities in the process of approving special permits for events by using the maximum number of attendees to estimate traffic impacts.

Problem Statement

Unlike with most land uses, when new agritourism land uses are proposed, transportation planners and engineers have limited guidance available to make appropriate and sound recommendations regarding entrances and other traffic improvements. A similar situation exists when existing agritourism operations are to be expanded.

Background

VDOT's involvement in the local land use permitting process includes granting entrance permits for new uses. Two broad categories of entrances, commercial and residential, are typically considered, and each is associated with specific rules and regulations. For example, according to the *Code of Virginia* (hereinafter *Code*), VDOT has the authority to close a commercial entrance if necessary but not a residential one (*Code* §§ 33.2-223, 33.2-241, and

33.2-245). Further, there are several types of commercial entrances, which are classified by traffic volume. Because the proprietor of an agritourism land use often resides on the property, it can be difficult to determine whether an entrance should be designated commercial or residential.

One key factor in the process of granting an entrance permit, as well as in the process of recommending street improvements and strategies for safety or capacity, is trip generation data. These data are available in the Institute of Transportation Engineers' (ITE) *Trip Generation Manual* (hereinafter *ITE Manual*) (ITE, 2012). The data include trip rates for various types of land uses and contexts based on prior studies of traffic entering and leaving specific land uses. The process for collecting trip generation data is described later.

Virginia Law

Virginia law defines an "agritourism activity" as "any activity carried out on a farm or ranch that allows members of the general public, for recreational, entertainment, or educational purposes, to view or enjoy rural activities, including farming, wineries, ranching, historical, cultural, harvest-your-own activities, or natural activities and attractions" (*Code* § 3.2-6400). Breweries are not included in the definition but are defined in *Code* § 4.1-500. Wineries appear in both *Code* sections; farm wineries are specifically defined in *Code* § 4.1-100. For the purposes of this study, rural breweries were considered to be similar to agritourism uses, although the *Code* does not explicitly define them as such. This study is not necessarily concerned with "agricultural operations" as defined in *Code* § 3.2-300 but rather with agritourism activities and land uses, which would in some cases relate to agricultural operations, such as when an agricultural product offered for sale is cultivated on the same property.

Other relevant sections of the *Code* included the following.

- *Code* § 33.2-240 addressed connections to highways from private roads leading to and from private homes. Guidance was limited to a statement that the Commissioner of Highways shall permit connections to provide "safe and convenient means of ingress and egress."

- *Code* § 33.2-241 covered connections to highways for commercial establishments. This section allowed for "access management standards for the location, spacing, and design of entrances" and "minimizing the impact of such ingress and egress on the operation of such highways" in providing the same "safe and convenient means of ingress and egress." It gave requirements for permits and for the person desiring the entrance to pay for its construction meeting VDOT design standards and those of the Land Use Permit Manual, seek joint use with adjacent property owners, and maintain the entrance.

Indirectly relevant was *Code* § 15.2-2288.3 regarding licensed farm wineries, which preempted localities from regulating certain activities of a licensed farm winery. The section did not directly address transportation until 2014, when *Code* § 15.2-2288.3:1, which addressed "limited brewery licenses" for agricultural breweries manufacturing no more than 15,000 barrels of beer annually, was added. The final legislation (SB 430, 2014) stated: "Any locality may exempt any brewery licensed in accordance with subdivision 2 of § 4.1-208 on land zoned agricultural from any local regulation of minimum parking, road access, or road upgrade requirements." (The original legislative proposal had barred localities from imposing minimum parking, road access, or road upgrade requirements without "a substantial impact on the health, safety, or welfare of the public.")

Code § 3.2-300 through 302, among other sections, addressed "right to farm" issues in Virginia, barring localities from requiring special-use permits for protected agritourism activities but not specifically addressing transportation improvements.

Other Considerations

Agritourism land uses have received growing attention in parts of Virginia. Areas that seek to maintain a rural character while encouraging tourism and growing an economic base may find these uses particularly attractive. As these enterprises flourish, challenges can arise.

One example is at farm wineries, many of which host weddings and other events in addition to conducting their daily business of wine tastings and sales. Virginia is home to more than 250 wineries, the fifth highest state count in the United States, and more than 1.6 million tourists visited Virginia wineries in 2013 (Virginia Office of the Governor, 2014). In addition to a major economic impact, the industry has an impact on auto trips. Larger events can lead adjacent residents to express concerns about traffic and noise, and some local governments have sought to limit events as a result. The Virginia legislature expressly limited some local ability to regulate "usual and customary activities and events" of farm wineries, breweries, and agricultural operations (*Code* §§ 15.2-2288.3, 15.2-2288.3.1, and 15.2-2288.6). VDOT's authority regarding entrances was unaffected, and localities remain able to enact reasonable regulations for activities and events where there is a substantial impact on the health, safety, or welfare of the public, although the law did not provide specific guidance or thresholds (Tubbs, 2014b). For example, Albemarle County enacted an ordinance in 2014 requiring an administrative zoning clearance for farm events or sales generating more than 50 vehicle trips per day and a special use permit for farm or farm brewery events with more than 200 attendees; county regulations already required a special use permit for farm winery events exceeding 200 attendees (Tubbs, 2014a, 2014b).

Agritourism land uses have two very different types of trips: non-event and event trips. Non-event trips, i.e., daily trips such as for wine tasting or berry picking, are expected to have low to moderate vehicle volumes and be scattered throughout the day, with seasonal peaks. Event trips, i.e., related to events such as weddings, are more likely to be associated with high vehicle volumes in a small time span, typically in the evenings and on weekends or holidays. As noted, this study focused on determining non-event daily trip volumes.

PURPOSE AND SCOPE

The purpose of the study was to provide VDOT staff with guidance on estimating trip generation for agritourism land uses as accurately as possible. After the determination that clear guidance did not already exist for these specific land uses, additional study and analysis were conducted in order to develop such guidance based on the Virginia experience.

The study addressed two questions:

1. Are trip generation rates for agritourism land uses in Virginia substantially different from rates for related land uses shown in the *ITE Manual* (ITE, 2012)?

2. What amount of variation in trips generated by agritourism land uses in Virginia is explained by observable land use factors (e.g., acres planted or square feet of event space)?

METHODS

To answer the two questions, three tasks were performed:

1. A review of the literature was conducted to establish the state of the practice regarding established methods for trip generation estimation in general and agritourism trip generation in particular.

2. Trip data were collected from selected agritourism land uses in Virginia.

3. The data collected in Task 2 were compiled and analyzed in the manner recommended by ITE (2004) in order to establish local trip generation rates.

Literature Review

The Transport Research International Documentation (TRID) database was used to identify literature published since 1975 on agritourism trip generation rates and the trip generation process in general. The identified literature was reviewed to determine how to collect trip generation data for Task 2 in accordance with established methods for trip generation estimation. Provisions of the *Code* and VDOT's *Road Design Manual* (VDOT, 2005) relating to residential and commercial entrances and agritourism activities were also reviewed.

Data Collection

The data collection procedure was based on recommendations from ITE's *Trip Generation Handbook* (hereinafter *ITE Handbook*) (ITE, 2004). Key considerations included the selection of an independent variable on which to base the data collection and analysis. The independent variable was to be "related to the land use type and not solely to the characteristics of the site tenants" and was to be information that is typically available when a new use is proposed.

Potential independent variables were identified by a review of the literature and consultation with VDOT staff. In addition, inquiries were sent to local planners in the counties of Albemarle and Nelson to find out what information might typically be known or available when land uses are proposed, which is the stage when VDOT typically reviews land use proposals (i.e., when a rezoning or special use permit is requested). These adjacent counties in central Virginia were selected because they each have a relatively high number of farm wineries but have different local review and approval processes. They also represent different contexts that can be found across Virginia: Nelson County (population 15,074) has a few small towns but is primarily rural and has a small planning staff, whereas Albemarle County (population 103,707) has a larger planning department and is a rural area with small towns that surrounds a ring of urban and suburban development adjacent to the City of Charlottesville. (Population estimates are for July 1, 2014, and are from the Weldon Cooper Center for Public Service, 2015).

Selecting Sites

ITE (2004) noted that common practice was to collect data from at least three, and preferably at least five, representative sites to establish a trip generation rate. A representative site was described as having at least 85% occupancy, being at least 2 years old, and having characteristics making data collection safe and easy.

Based on recommendations from five of VDOT's transportation and land use directors, a list of 37 relatively well-established agritourism sites in Virginia, including pick-your-own farms/orchards, wineries, cideries, produce stands, farm markets, and a brewery, was developed.

A subsample of this list was then created based on the following considerations:

- geographic location (given a goal of studying sites from different parts of the state)
- paved vs. unpaved driveway (some automated traffic counters could be used only on paved surfaces)
- dedicated driveway vs. one shared with other land uses and configuration of other driveways or cross streets on adjacent road (to avoid capturing trips not destined for the agritourism land use)
- volume and speed of traffic on adjacent road (to avoid sites where crews would be at a safety risk when placing and removing counting equipment on a major road)
- review of the website of each agritourism site (some sites were removed from consideration because they included other land uses, such as a restaurant, camp, or

lodge; other sites were removed from consideration because they were for sale, under construction, using buildings termed "temporary," or not offering a key element of their usual operation, such as pick-your-own fruit, because of a particular issue).

Representatives of the 20 remaining candidate sites were contacted by telephone with an invitation for their proprietors to answer a questionnaire about the characteristics of the site. The introductory script and questions used in this contact are provided in Appendix A. Representatives of 10 sites (50%) provided responses. A plan to collect data for 3 pick-your-own farms and 3 wineries was amended to include only wineries and cideries because the representatives of the farms either declined to participate or did not respond to the invitation to participate. The revised data collection plan involved 5 winery/cidery sites. In order to obtain permission to collect data, it was necessary to keep the identity of each site confidential, which is consistent with ITE's procedures (2004).

Conducting Traffic Counts

According to ITE (2004), the best time period for conducting counts is when "the combination of site-generated traffic and adjacent street traffic is at its maximum." For automatic counts, a 7-day count was recommended. Because trip volumes generated by agritourism land uses have seasonal variation, "time periods representing the 30th to 50th highest hours of the year may be used." For this study, it was assumed that this time period would correspond to the fifth busiest day of the year.

Permission to place counting equipment was requested of each proprietor, as recommended by ITE (2004). In most cases, the ideal location to place counting equipment to ensure count accuracy and safety for technicians was private property, making permission a necessity. Site contacts were also asked about any events that might affect traffic counts during the count period. All five sites studied were rural wineries/cideries in northern, central, or southern Virginia within a 30-minute drive of a town or urbanized area.

Technicians from VDOT district offices set up and removed automatic traffic counting equipment (pneumatic tubes) at each site. Counts were to be conducted for 7 full 24-hour days to include the day (or one of the days) identified as the fifth busiest day of the year, but technicians deviated from this research plan in some instances (presumably because of other work demands or for efficiency in deploying and retrieving count equipment), as indicated in Table 1. Count increments were not specified in the research plan. Data for Sites 1 and 5 were reported in 1-hour increments, whereas those for adjacent streets were reported in 15-minute increments.

Pneumatic tubes were used to obtain automated traffic counts at entrances and exits to each site. Because the goal was simply to quantify the number of vehicles entering and exiting each site for daily business, there was no need to consider automobile occupancy rates or to separate counts by vehicle classification. After the researcher received the count data set for a site, the data set was sent by e-mail to the site contact for use as desired.

Table 1. Reported Fifth Busiest Days, Dates of Traffic Counts, and Site Comments for Study Sites

Site No.	Reported 5th Busiest Day	Count Dates	Comments
1	Labor Day weekend. Memorial Day weekend is the busiest; all of October is pretty busy.	8/27/14–9/2/14	Data were reported in 1-hr increments. [a]
2	The Saturday of one of these: Memorial Day weekend, Labor Day weekend, the last weekend in September, or any weekend in October	10/9/14–10/16/14	Data were reported in 15-min increments. Counters were activated midday on Day 1 and deactivated midday on Day 8 (both Thursdays); for analysis purposes, these two 12-hr periods were added together to represent 1 full day. No traffic volume data were available for the street adjacent to this site.
3	A weekend in mid-September	10/22/14–10/28/14	Data were reported in 15-min increments. Permission to count was obtained on October 2, 2014; the researcher chose to collect data immediately rather than wait 11 months for a mid-September weekend. A count was completed in early October, but equipment was placed on only one of the site's two driveways, so the count was redone in late October. Counters were activated midday on Day 1 and deactivated at 8 A.M. on Day 7; because these two time periods were on different weekdays and because together they provided only 20 hr of data, both were excluded from the analysis.
4	A Saturday in November	11/5/14–11/11/14	Data were reported in 15-min increments.
5	A Saturday in October	10/24/14–10/26/14	Data were reported in 1-hr increments. [a] Weekday data were based only on a count for a Friday, the only weekday the site was open to visitors. This site was determined to have a substantially different context than the other 4 sites, which were all relatively popular retail or destination wineries/cideries. This site had elements of agritourism such as a tasting room and outdoor space for picnics and events, but its management advised that although it was open to the public for tastings, it did very little retail sales business, with wholesale selling representing the vast majority of its business.

[a] Count increments were not specified in the research plan because the primary time span of interest was a full day and because it was assumed that a consistent counting method was used across VDOT. In fact, data for Sites 1 and 5 were reported in 1-hr increments, whereas those for adjacent streets were provided in 15-min increments, so the hour of site data closest to the street's actual peak hour was used to calculate volumes during street peak hours for Sites 1 and 5.

Trip generation rates have systematic variation (variability based on factors not under statistical control) and random variation (variability attributable to chance). This study attempted to eliminate known sources of systematic variation in the data by identifying factors that might influence rates, such as season of the year, and then by collecting data in a way that controlled for these factors. Standard practices for collecting trip generation data are specified in the *ITE Handbook* (2004), which includes guidance for steps data collectors need to follow in order for ITE to accept their data. These steps help minimize systematic variation.

Unlike systematic variation, random variation cannot be controlled during the data collection process. For example, even if two counts were conducted on summer Saturdays at the same winery, the number of trips generated would be nominally different. Appropriate statistical testing was conducted to address random variation.

Data Compilation and Analysis

Prior to statistical analysis, two Census-related independent variables were constructed with the use of GIS software. Statistical analyses were conducted with the data collected.

GIS Analysis

Two independent variables were constructed with the use of Census data and GIS software: population within a 60-minute drive and number of households within a 60-minute drive. Because these variables are based only on publicly available data and the site location, it was thought that they could be useful for trip estimation in cases where local governments do not require any site data along with land use proposals. The value of 60 minutes was selected arbitrarily; another value could be chosen if desired.

The following basic procedure was used to construct these variables in ArcGIS version 10.0 with the Network Analyst extension; Appendix B shows the full step-by-step procedure.

1. Add the following data to a GIS map:

    - Esri U.S. streets layer or similar street network dataset

    - 2010 Census Block file containing population and household data

    - a point layer containing the location of the agritourism land use to be studied. Locations of existing wineries were extracted from a publicly available shapefile (Virginia Economic Development Partnership, 2011); new locations could be manually digitized.

2. Configure the Network Analyst environment and create a new service area analysis layer. Set the properties of the service area analysis layer to use Minutes as the Impedance and a default break value of 60. This configures the analysis layer to compute the area within a 60-minute drive of the point. Solve the analysis using the point layer representing the site location as a Facility.

3. Select the blocks with centroids within the service area polygon and sum their populations and/or households.

Step 3 of this procedure (Step 8 of the full procedure in Appendix B) is an approximation using the block centroids. This relatively simple method was employed along with finer grained block level data to obtain a planning-level estimation.

Statistical Analysis

For each site, traffic volume information was summarized as follows:

- 24-hour average weekday volume

- 24-hour Saturday volume
- 24-hour Sunday volume
- 1-hour volume during the morning and afternoon peak hour for the adjacent street
- morning and afternoon weekday average peak hour and volume
- weekend average peak hour and volume.

To obtain the 1-hour volume during the adjacent street peak hours, the most recent volume data available as of November 2014 for each site's adjacent street (i.e., the street serving the site's main entrance; see Figure 1) were acquired from VDOT's Traffic Engineering Division. The data were collected in 2011, 2012, or 2014, depending on the site, and no data were available for the street adjacent to Site 2.

Because data collection results indicated that Saturday and Sunday volumes were higher than weekday volumes, additional analysis was performed for these weekend days. In accordance with ITE guidelines (ITE, 2004) for the type of analysis to conduct based on data sample size, weighted average trip generation rates were calculated for independent variables with two or more data points (i.e., where values for the variable existed for two or more of the sampled sites). Where three or more data points were available, a standard deviation was calculated, more precisely defined as the standard deviation of the weighted average trip generation rate for each site. With four or more data points, a linear regression model was created for each variable (ITE reports the equation only if the R^2 is greater than or equal to 0.5).

To quantify the uncertainty that results from use of a trip generation rate that is based on data from a small number of sites, a prediction interval was calculated for the independent variable whose linear regression equation had the highest R^2, i.e., Saturday trips per peak season employee, excluding Site 5, as explained later.

A closer examination of the fit of a regression equation for the Census-derived variable of population within a 60-minute drive led to calculation of a 95% confidence interval of the mean for a cluster of three data points. The normal distribution was also applied to illustrate the probability of a site generating a certain number of trips, given the mean and standard deviation.

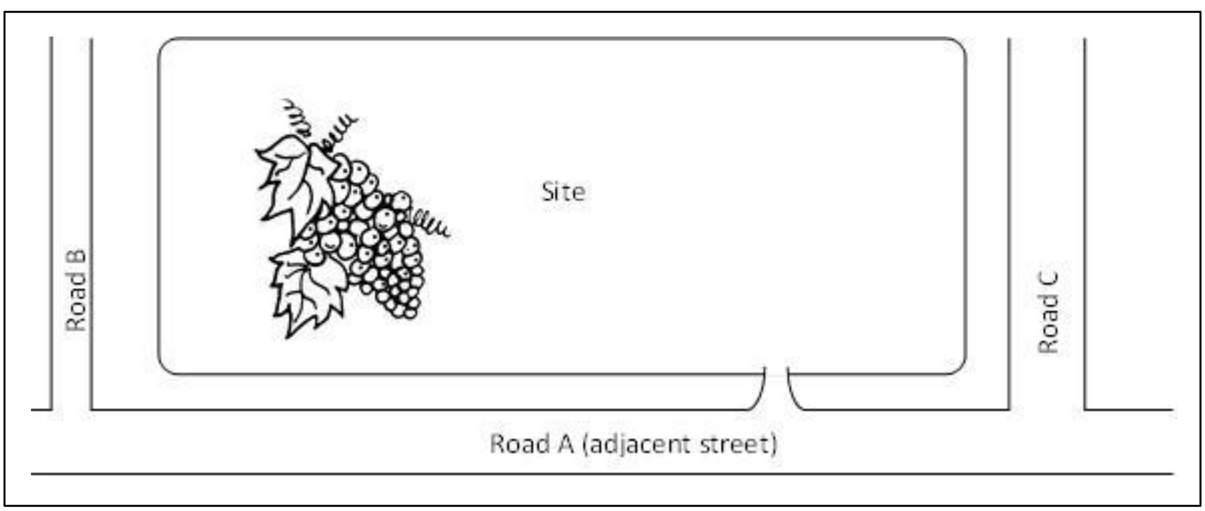


Figure 1. Depiction of Generic Site Showing Adjacent Street (Road A) and Other Streets (Roads B and C)

Use of a hypothesis test (comparison of means or *t*-test) was demonstrated for one ITE land use classification to examine the hypothesis that the average Virginia agritourism trip generation rate differs significantly from the average ITE rate for a related land use.

Multivariate linear regression models were not developed because of the limited number of sites and the uncertainty about which independent variables would be available in a given locality.

RESULTS

Literature Review

Trip Generation Data Collection Process

The *ITE Handbook* (2004) provided details of the trip generation data collection process. The typical process for estimating trip rates is to collect traffic count data at existing sites that are representative of a land use category. For different time periods (e.g., weekend days vs. weekdays), the traffic counts are plotted against site characteristics that serve as independent variables. For ITE's purposes, it is not necessary to prove that an independent variable actually causes changes in trip volumes rather than vice versa; the correlation is the main focus. ITE (2012) assembles the results of multiple studies across the United States for many different land use types, and transportation planners and engineers make generalizations from these data. Several authors have criticized various aspects of the ITE trip generation process, primarily whether it is applicable to sites in mixed-use and/or transit-oriented areas (for example, Lee et al., 2012).

To use existing ITE data when evaluating a new site

> [t]he value of the independent variable for the [new] study site must fall within the range of data included [in ITE's existing data]. . . . The number of trips determined by either the rate or the equation should fall within the cluster of data points (i.e., the range of trip values) found at the study site's independent variable value. Otherwise, additional local data are needed.

Local data collection was also advised when a study site was not compatible with ITE land use code definitions, which appeared to be the case for agritourism land uses in general.

The *ITE Handbook* provided guidelines for executing a local trip generation study, which was recommended when published data did not fit the situation in question. Key considerations included the selection of an independent variable on which to base the data collection and analysis. The independent variable chosen should be "related to the land use type and not solely to the characteristics of the site tenants" and should be information that is typically available when new development is proposed. For some agritourism land uses, then, candidate independent variables might include number of seats, number of tasting stations, size of parking area, acreage planted, or frequency and size of events.

The *ITE Handbook* noted that although there was no simple statistical method to determine the number of sites that should be studied to obtain statistically significant trip generation results, common practice was to collect data from at least three, and preferably at least five, representative sites to establish a trip generation rate. A representative site was defined as being reasonably full, mature, and with characteristics making collecting data easy and safe.

As noted earlier, the best time period for analysis according to the *ITE Handbook* would be when "the combination of site-generated traffic and adjacent street traffic is at its maximum." With automatic counts, a 24-hour period was the minimum, 48 hours were preferred, and 7 days were ideal. Because trip volumes generated by agritourism land uses have seasonal variation, "time periods representing the 30th to 50th highest hours of the year may be used."

Arnold (1984) detailed the process used to develop trip generation rates based on Virginia data for several land uses, including selection of sites, collection of data, and analysis of data.

The Federal Highway Administration's *Traffic Monitoring Guide* (2013) contained typical time-of-day traffic patterns for rural areas and day-of-week traffic patterns for recreational trips. In rural areas, car traffic typically increases throughout the day to a single peak hour in the afternoon and then tapers off, in contrast to the dual peaks (morning and afternoon) typical of urban car travel. Recreational car travel has relatively constant volumes on weekdays with increased traffic on Fridays, Saturdays, and Sundays. These patterns provided useful background for the likely traffic patterns on streets adjacent to rural agritourism land uses.

Examples of Agritourism Trip Generation Rates

ITE Manual

The *ITE Manual* (ITE, 2012) contained no information for agritourism land uses, although some uses it included could be considered related. The general purpose of the *ITE Manual* is to provide the results of traffic counts compared to quantifiable site variables that could serve as proxies for the number of trips generated by a land use, which is typically closely related to business volume. For trip generation methods to be useful, causality need not be demonstrated, only a moderately strong bivariate correlation with traffic volumes.

The *ITE Manual* contained published trip rates for the land use categories of "amusement park," "nursery (garden center)," "specialty retail center," "drinking place," and "quality restaurant," none of which individually can represent exactly the character of all Virginia agritourism uses, although each represents some portion of some agritourism uses.

Table 2 lists ranges of trip rates for the peak hour of the generator (i.e., the land use under study). Table 3 gives the range for weekdays and Sundays instead for the specialty retail center land use, which had no data for the peak hour of the generator. As shown in these two tables, trip rates included in the *ITE Manual* can vary substantially, often by an order of magnitude or more. An example can help explain the values presented in Tables 2 and 3. For the specialty retail center land use, the *ITE Manual* provided several tables. Two tables plotted trips per 1,000 square feet gross leasable area on a weekday; one was for the A.M. peak hour of the generator (i.e., the hour during the morning when the land use generates the most trips), and one was for the P.M. peak hour of the generator. The lowest trip rate (4.59 trips per 1,000 square feet gross leasable area) was observed at one of three sites with data for the P.M. peak hour of the generator. The highest trip rate (14.08 trips per 1,000 square feet gross leasable area) was observed at one of four sites with data for the A.M. peak hour of the generator. Table 2 shows these two values to indicate the variation in the ITE study data for each land use of interest. ITE also provided trip rates per employee for this land use, but these rates were shown for full days rather than for the A.M. and P.M. peak hour of the generator. Thus, Table 3 indicates the lowest (8 trips per employee per day, which was observed at one site on a Sunday) and highest (25.95 trips per employee, which was observed at one site on a Saturday) trip rates that were given.

Each of these land use categories is examined here. In some cases, values are given for R^2, which is a measure of how well a factor accounts for the variation in a dependent variable (trips, in this case). Expressed on a scale of 0 to 1, R^2 values closer to 1 indicate that the relationship is stronger than for lower R^2 values. ITE publishes best fit regression curves and R^2 values only when the R^2 is at least 0.50, there are at least four data points, and the relationship is in the expected direction (i.e., the number of trips increases as the size of the independent variable increases).

Table 2. Range of Rates (Trips per Independent Variable) for A.M. and P.M. Peak Hour of Generator (All Days)

ITE Land Use Name	Code	Independent Variable									
		Employees		1,000 Sq. Ft. Gross Floor Area		Acres		1,000 Sq. Ft. Gross Leasable Area		Seats	
		Low	High	Low	High	Low	High	Low	High	Low	High
Amusement Park	480	0.09	2.55	—	—	0.68	22.92	—	—	—	—
Nursery (Garden Center)	817	0.26	30.14	2.08	45.5	0.6	150.71	—	—	—	—
Specialty Retail Center	826	—	—	—	—	—	—	4.59	14.08	—	—
Drinking Place	925	—	—	3.73	29.98	—	—	—	—	—	—
Quality Restaurant	931	—	—	0.87	15.89	—	—	—	—	0.05	0.5

ITE = Institute of Transportation Engineers; — = *ITE Manual* (ITE, 2012) did not include rates for a particular combination of independent variable and land use.

Table 3. Range of Rates for Weekday and Weekend Days for Land Uses Without Peak Hour Data

ITE Land Use Name	Code	Employees	
		Low	High
Specialty Retail Center	826	8	25.95

ITE = Institute of Transportation Engineers.

- *Amusement Park.* The *ITE Manual* defined an amusement park as containing "rides, entertainment, refreshment stands and picnic areas." Belvedere Plantation near Fredericksburg offers rides (hayride, pedal tractors, barrel train); entertainment (pig races, fun barn, corn maze); refreshment stands (restaurant/grill, bakery); and picnic tables in the parking area (Belvedere Plantation, 2013). It is thus an example of an agritourism land use that has characteristics similar to those of a small amusement park.

  The *ITE Manual* trip rates used employees and acres as the independent variables and were based on 1970 and 1987 data from three California and Oklahoma sites with 108, 300, and 600 employees and 697, 2,200, and 3,000 parking spaces, respectively. Charts based on two studies presented weekend data based on (1) Saturday or Sunday and (2) the peak hour of the generator. A table provided weekday data based on a single study. With such a small sample, average rates are not particularly meaningful other than to illustrate some minimum and maximum trip rates; full-day Saturday/Sunday rates ranged from 9.17 to 25.2 trips per employee and from 82.5 to 198.97 trips per acre.

- *Nursery (Garden Center).* Farm stands and markets that sell produce share some characteristics with this ITE land use, defined as "a free-standing building with an outside storage area for planting or landscape stock." The definition noted that trip characteristics at nurseries have seasonal variations, which is also expected for most agritourism land uses. ITE data came from studies in the 1980s in California and were presented at varying temporal levels for the independent variables of employees, gross floor area, and acres. Only the employee variable had data with correlations suitable for publishing fitted curve equations. The time period with the best fit was on a weekday (R^2 of 0.81), when rates ranged from 10.71 to 53.86 trips per employee.

- *Specialty Retail Center.* The ITE definition for this land use ("small strip shopping centers that contain a variety of retail shops") does not appear to encompass any agritourism land use, but some wineries and farm markets do include a mix of retail uses. For example, in addition to its produce, a farm market might sell clothing, dry goods, and prepared foods. The ITE data were based on sites in five states surveyed between the late 1970s and the 2000s and were presented for two independent variables: gross leasable area and employees. For the P.M. peak hour of adjacent street traffic, a reasonable fit for trips per gross leasable area was obtained (R^2 of 0.98) based on five studies, with rates of 2.03 to 5.16 trips per 1,000 square feet gross leasable area. Only three studies were based on the number of employees, with weekday and Saturday rates from 21.96 to 25.95 trips per employee.

- *Drinking Place.* The *ITE Manual* described a drinking place as containing "a bar, where alcoholic beverages and food are sold, and possibly some type of entertainment, such as music, television screens, video games, or pool tables." Restaurants with bars were excluded. Available studies used the gross floor area as the independent variable but did not find a consistent relationship with trips. Two charts based on studies conducted in 1987, 1995, and 1997 in Colorado, Oregon, and South Dakota, respectively, did not meet the conditions to show fitted curve equations. The range of rates was 3.73 to 29.98 trips per 1,000 square feet of gross floor area for a peak hour, which may be too large a range to be considered useful for estimating trips.

- *Quality Restaurant.* With more related published studies than most other land uses summarized here (studies throughout the United States from the 1970s through the 1990s), the *ITE Manual* defined this land use as consisting of "high quality, full-service eating establishments with typical duration of stay of at least one hour," typically open for dinner only or for lunch and dinner, and that may require reservations, in contrast with those in the "High-Turnover (Sit-Down) Restaurant" category. Some agritourism land uses, such as breweries serving a full menu, appear to fit the definition of a quality restaurant. A VDOT analysis of an on-site brewery with associated restaurant in the Town of Floyd applied this land use type (Johnson, 2013).

  Quality restaurant study data for the weekday P.M. peak hour of the generator (11 studies) ranged from 0.18 to 0.44 trips per seat, with an R^2 of 0.74. Data based on gross floor area had lower R^2 values, when given.

  Agritourism uses often have outdoor seating. As such, a note in the *ITE Manual* for "quality restaurant" was instructive: "The outdoor seating area is not included in the overall gross floor area. Therefore, the number of seats may be a more reliable independent variable on which to establish trip generation rates for facilities having significant outdoor seating."

Other Studies

One study from the 1970s covered trip generation for scenic areas (Miles and Smith, 1977), not quite matching the desired land uses of agritourism activities.

There were several relevant studies regarding areas of California including San Diego and the counties of Sonoma, Riverside, and Napa.

- *San Diego.* This study used surveys and traffic counts for three types of wineries (County of San Diego, Department of Planning and Land Use, 2010). Data collected at three representative wineries, each with a different geographic classification, found the highest traffic at the "backcountry-destination" site, with the "suburban" site following and the "backcountry-rural" site having the fewest trips. The highest observed traffic for a single winery was 40 weekday average daily traffic and 160 weekend average daily traffic, and the amount of wine produced annually (cases of wine per year, based on a case size of approximately 2.38 gallons) was used as an independent variable. Calculated weekday trip generation rates ranged from 5.9 to 11.8 trips per 1,000 cases per year. Weekend values ranged from 11.8 to 40 trips per 1,000 cases.

- *Sonoma County.* A draft report from 2011 indicated that Sonoma County used a winery trip generation form to estimate traffic volumes. The assumed daily rate used was 3 trips per employee plus 0.8 trip per tasting room visitor. Winery driveway counts showed that 10% of daily trips were in the afternoon peak hour and 13% were during the weekend midday peak hour (Aguayo, 2011).

  Sonoma County also used trip generation curves to determine traffic impact fees based on case production for two categories: "winery only" and "winery with tasting." The curves were created in 1998 based on a few counts, traffic generation estimates, and many assumptions (Kottage, 1998). For wineries that produced 50,000 cases or less per year only, the county used the following fitted curve, where "Cases" is the number of cases produced per year:

  $$\text{One-way trip ends} = -0.00000001(\text{Cases})^2 + 0.0013(\text{Cases}) + 9.5$$

  The application of this curve for wineries that produced 50,000 cases or less per year yields trip generation figures of fewer than 50 trips per day, which is the upper threshold for VDOT's category of low volume commercial entrance.

- *Riverside County.* This study collected driveway traffic counts at five wineries, among other tasks, to create a travel demand model (Pack and Johnson, 2011). The study provided the number of trips generated; the values of explanatory independent variables (restaurant size, parking spots, and number of hotel rooms); and a table of regression coefficients relating the number of trips at each site to the three independent variables. A limitation of the study is that information about statistical significance was not given, which is to be expected because the linear regression equation consisted of four terms (the three independent variables and a constant) and four sites serving as data points (not enough to allow one to test any of the variables for statistical significance).

  However, when the author of the current study used these same data with just one independent variable (the number of hotel rooms), the variable was either statistically significant or approached significance ($p = 0.04$ for the peak weekend coefficient and $p = 0.06$ for the peak weekday coefficient). Further, the equation explained more than 80% of the variation. Thus, the data collected by Pack and Johnson (2011), although based on a limited number of sites, do suggest that activity (in this case, the number of hotel rooms) explains to some extent the number of trips observed at wineries in California. The results may also suggest that some California destination wineries differ from Virginia wineries, which may be seen as the destination for a day trip but which do not typically include hotel rooms.

- *Napa County.* Consultants collected 7-day traffic counts at 22 wineries in October 2014 (Fehr & Peers, 2014). They also surveyed winery patrons in person and gathered cell phone trip-making data for vehicle trips across Napa County. The data analysis report for the Napa County study became available after the researcher had completed data collection for the present study.

The Napa County study used multivariate linear regression to estimate models for average Monday to Wednesday weekday, Thursday, Friday, Saturday, and Sunday trip generation rates for all 434 wineries in the county. The authors noted that wineries' reluctance to participate in the study affected the sample size for data collection. Three independent variables were included in the final analysis:

1. annual gallons produced
2. whether the winery was located on the Napa Valley floor
3. whether the winery required advance appointments.

The resulting models had R^2 values of 0.79 to 0.86. When applied to all 434 wineries, the models estimated that total daily vehicle trip generation from all Napa County wineries exceeded 50,000. Combined with analysis of cell phone and survey data, the study found that winery trips by employees or visitors constituted 34% of all Saturday trips in the county.

Several variables from a preliminary analysis were removed when the final analysis was developed. Variables representing parking supply and employees were removed because of the perception that those variables were caused by demand rather than being predictors of demand. Square footage and approved visitation (the maximum number of visitors per day or week a site is allowed under its local permit) were removed because of a high correlation with the gallons-produced variable that remained in the analysis.

VDOT *Road Design Manual*

VDOT's *Road Design Manual* (VDOT, 2005) included definitions for the following entrance types:

- **Commercial Entrance:** Any entrance serving land uses that generate more than 50 vehicular trips per day or the trip generation equivalent of more than five individual private residences or lots for individual private residences using the methodology in the Institute of Transportation Engineers Trip Generation.

- **Moderate Volume Commercial Entrance**: A commercial entrance along highways with shoulders with certain site and design criteria reduced. Site requirements are: maximum highway vehicles per day: 5,000, maximum entrance vehicles per day: 200, maximum entrance percent truck trips of vehicles per day: 10%.

- **Low Volume Commercial Entrance:** Any entrance, other than a private entrance, serving five or fewer individual residences or lots for individual residences on a privately owned and maintained road or land uses that generate 50 or fewer vehicular trips per day using the methodology in the Institute of Transportation Engineers Trip Generation.

- **Private Subdivision Road or Street Entrance:** A commercial entrance for a road or street that serves more than five individual properties and is privately owned and maintained.

- **Private Entrance:** An entrance that serves up to two private residences and is used for the exclusive benefit of the occupants or an entrance that allows agricultural operations to obtain access to fields or an entrance to civil and communication infrastructure facilities that generate 10 or fewer trips per day such as cell towers, pump stations, and stormwater management basins.

With the exception of a sight distance requirement, the *Road Design Manual's* design for a low volume commercial entrance was identical to that for a private entrance, with a surfaced width of 12 to 24 feet and a minimum graded width of 16 feet. Moderate volume commercial entrances had a required width of 18 to 30 feet, and two-way commercial entrances had a required width of 24 to 40 feet with a minimum of 30 feet if not on a local street. Commercial entrances had additional requirements such as longer throat lengths, curb and gutter or curbing along the entrance, and entry/exit tapers.

Summary of Literature Review

There was not a broad body of quantitative data regarding agritourism trip generation. National guidance from ITE included related uses but not the uses of interest specifically; they were examined only in limited studies and in a California context.

Collected Data

Table 4 lists the results of inquiries sent to local planners in the counties of Albemarle and Nelson about what information on potential independent variables would typically be available (i.e., either required by the locality or likely to be provided at the locality's request) when new development was proposed. (The exact question was: "Which of the following are typically available when agritourism land uses are proposed?") The differing responses from these adjacent counties with different contexts illustrate the difficulty of selecting an independent variable or set of variables that will be useful statewide.

Table 4. Local Availability of Data on Potential Independent Variables at Land Use Proposal Stage

Variable	Albemarle County	Nelson County
Number of seats	Good estimate of indoor seats	Typically not known
Number of tasting stations for wineries	Good estimate	Typically not known
Size of tasting room for wineries	Good estimate	Typically not known
Size of interior space	Good estimate	Sometimes provided/defined
Size of parking area or number of spaces	Good estimate	Typically provided/estimated
Acreage planted	Good estimate	N/A[a]
Frequency and size of events	Often unsure of frequency; depends on how initial events go	Typically not provided/defined, but alluded to as a conceptual element of the plan/design
Production for wineries (cases per year)	Somewhat difficult to know	N/A
Expected number of employees at peak season	Unsure	Typically provided/estimated
Expected number of daily visitors at peak season	Very unsure	Typically not provided/estimated

[a] "N/A" means that based on limited experience, the respondent could not address whether the variable would be known.

Although the planner for the more populous Albemarle County expected to have good estimates of the number of indoor seats; the number of tasting stations; and the size of the tasting room, interior space, and parking area, the planner for the more rural Nelson County expected to know only estimates of parking area, the expected number of employees at peak seasons, and possibly the size of interior space. Neither planner expected to know the frequency and size of events, annual production, or expected number of daily visitors at peak season.

The planners also noted several other items of useful background information:

- Depending on the locality, these land uses might not need more than a building permit, which would not invoke substantial local review requirements. For example, at the time, Albemarle County did not require zoning clearances from wineries that were not planning to host events of more than 200 attendees.

- Proprietors of agritourism land uses tend to introduce products and services slowly and scale up operations incrementally. If and when a site becomes popular, growth pressures and traffic increase rapidly.

- The size of interior space may not be an accurate predictor for land uses that rely on having plenty of outdoor space available.

- Outdoor fields can become overflow parking areas, which are typically not formalized as parking areas if used infrequently.

- Limited data are available initially, often depending mostly on who the applicant retained as a traffic consultant. More information is sometimes made available at various points in the review process, such as at a site review committee meeting, as part of developing a staff report, or at the hearing of the planning commission.

- Some localities do not have a well-defined set of information that is requested or required of applicants but might be able to implement such a checklist in the future.

Site Characteristics and Trip Volumes

The questionnaire response from Site 4 indicated that it had a parking area of 100 square feet. Because this was smaller than a single typical parking space (9 feet by 18 feet), the response was deemed invalid. The distance measurement feature of Google Maps was used to estimate the size of a gravel parking area at the site, visible from Google's aerial imagery. This was roughly 75 feet by 75 feet, or 0.13 acre, so that value was used for Site 4's parking area size. (As with other sites, it is possible that additional parking occurs in fields when this area is at capacity.)

Table 5 summarizes the results for site-specific data (independent variables) including the Census-derived variables. Table 6 provides notes about unique characteristics or circumstances for each site. As noted previously, the data are for a small sample of sites and have substantial variability. Although not by any means a complete picture of agritourism traffic patterns in Virginia, this information can begin to address the previous complete lack of Virginia data on the topic.

Site 5 was determined to have a substantially different context than the other sites, which were all relatively popular retail or destination wineries/cideries. Site 5 has elements of agritourism such as a tasting room and outdoor space for picnics and events, but its management advised that although it is open to the public for tastings, it did very little retail sales, with wholesale representing the vast majority of its business.

Table 7 shows each site's trip volumes (total of entering and exiting vehicles at all driveways) at various scales of analysis. The weekday peak hour volumes for each site were higher than the site's 1-hour volume during the adjacent street's peak hours. That is, the peak hour for the site entrance was at a different time than the A.M. and P.M. peak hours of the adjacent street.

Table 5. Independent Variables for the Five Sites

Independent Variable	Site 1	Site 2	Site 3	Site 4	Site 5
Number of marked parking spaces	40	0	90	0	0
Number of unmarked parking spaces	Unknown	300	Unknown	16	Unknown
Size of parking area (acres)	5	4	1	0.129	0.115
Square feet of total interior space	30,000	16,500	Unknown	1,440	7,500
Square feet of tasting room	4,032	7,000	1,400	1,380	1,500
Number of tasting stations	4	6	25	2	1
Number of acres planted	53	30	26	14	5
Annual production (cases)	14,000	9,000	35,000	Multiple	1,000
Number of employees, peak season	40	90	25	14	2
Population within 60-minute drive	433,922	1,975,753	326,127	346,400	233,880
Households within 60-minute drive	167,198	713,382	122,272	137,047	92,989

Unknown = a respondent said a site had the factor but did not know or did not provide a quantity; Multiple = site produced various products (e.g., fresh fruit and beverages) and provided information for all of them.

Table 6. Site Notes

Site No.	Notes
1	One tasting station on weekdays. Number of employees does not include event staffing.
2	Tasting stations accommodate 120 guests. Seeks to be a destination winery, encouraging people to stay longer and share the day with friends and family.
3	Has additional off-site planted acreage. Can accommodate 150-person events.
4	Combined with an orchard; number of acres planted reflects all fruit trees. Tasting room was expanded from 575 to 1,380 square feet within 6 months before the count dates. Production was 500-1,000 bushels of fruit, 2,500 gallons of fresh juice, and 7,500 gallons of alcoholic beverage. (Because any one of these numbers would not represent the site's total production, the site was excluded from analysis for the production variable.) At peak season, there are 4 full-time and 10 part-time employees. Size of parking area was estimated based on aerial imagery.
5	Does very little retail business; 99% of product is sold wholesale to other wineries for resale.

Table 7. Trip Volumes for the Five Sites

Measure of Trip Volumes	Site 1	Site 2	Site 3	Site 4	Site 5[a]
24-hour average weekday volume	370	192	261	91	4
24-hour Saturday volume	735	1,205	596	509	20
24-hour Sunday volume	878	1,173	431	351	8
1-hour volume during street A.M. weekday peak hour[b]	9	N/A	10	2	0
1-hour volume during street P.M. weekday peak hour[b]	28	N/A	32	5	1
A.M. peak hour volume	27	9	21	13	1
P.M. peak hour volume	51	26	38	14	1
Weekend peak hour volume	148	188	68	83	5

[a] Site 5 was excluded from some analyses because it was a primarily wholesale rather than retail operation.
[b] Data for Sites 1 and 5 were reported in 1-hour increments, and adjacent street data were provided in 15-minute increments, so for those sites, the hour of site data closest to the street's actual peak hour was used.

Results of Data Analysis

Tables 8 and 9 present average trip rates and statistical information based on Saturday data. For the analysis of all five sites and for each independent variable, Table 8 presents the number of cases (i.e., how many sites provided data on the particular variable; see Table 5); the mean trip rates per independent variable (if at least two cases); a standard deviation of the set of individual site trip rates (if at least three cases); and the R^2 value for a bivariate linear regression equation (if at least four cases). Certain variables as noted are shown in units of 1,000 for ease in displaying trip rates. If ITE's guidelines (ITE, 2004) are used, the regression equation or R^2 value of the following four variables with an R^2 value below 0.50 would not be shown: total interior space, tasting stations, acres planted, and annual production.

For example, the independent variable "size of parking area" was an available variable in five cases, i.e., for all five sites (see Table 8). The sites had 5, 4, 1, 0.13, and 0.11 acres, respectively, available for parking (Table 5). Traffic volumes were collected at each site on one Saturday, with results of 735, 1,205, 596, 509, and 20 trips, respectively (Table 7). The mean trip rate is calculated as the sum of these trips (3,065 trips) divided by the sum of the acreage available for parking (10.24 acres). That is, it is the average change in the number of trips per 1 unit change in the independent variable averaged across the five cases.

Table 8. Mean Trip Rates (Average Change in Number of Trips per 1 Unit Change in Independent Variable) and Statistical Information, Saturday Data, All Five Sites

Independent Variable	No. of Cases	Mean Trip Rate	Standard Deviation	R^2
Number of marked parking spaces[a]	2	10.2	—	—
Number of unmarked parking spaces	2	5.42	—	—
Size of parking area (acres)	5	299	1,636	0.54
1,000 square feet of total interior space	4	44.5	163	0.22
1,000 square feet of tasting room	5	200.2	166	0.72
Number of tasting stations	5	80.7	108	0.03
Number of acres planted	5	24.0	15.0	0.39
Annual production (1,000 cases)	4	43.3	54.4	0.04
Number of employees, peak season	5	17.9	10.3	0.89
1,000 people within 60-minute drive	5	0.924	0.755	0.69
1,000 households within 60-minute drive	5	2.49	1.97	0.69

[a] Only the two sites with marked parking spaces were used.

For each site, a value of trips per acre of parking can be calculated (i.e., 147, 301, 596, 3,942, and 174), and the standard deviation is the standard deviation of these five individual trips-per-acre values. The R^2 value reported for this variable in Table 8 is for a bivariate linear regression with size of parking area as the independent variable and number of trips as the dependent variable.

Because of the different context of Site 5, some analyses were performed a second time excluding data from Site 5. Table 9 presents the same information as Table 8 based on analysis without Site 5. The smaller number of data points means there are more empty cells in Table 9, and under ITE's conditions, two variables (size of parking area and number of acres planted) would not have regression equations or R^2 values shown.

As a comparison, Saturday trips vs. size of tasting room and employees are graphed in Figures 2 and 3, respectively, with and without Site 5. Appendix C includes all charts for Saturday and Sunday data with linear regression equations displayed where appropriate.

Table 9. Mean Trip Rates (Average Change in Number of Trips per 1 Unit Change in Independent Variable) and Statistical Information, Saturday Data, Excluding Site 5

Independent Variable	No. of Data Points	Mean Trip Rate	Standard Deviation	R^2
Number of marked parking spaces	2	10.2	—	—
Number of unmarked parking spaces	2	5.42	—	—
Size of parking area (acres)	4	301	1,806	0.44
1,000 square feet of total interior space	3	51.1	178	—
1,000 square feet of tasting room	4	220	129	0.95
Number of tasting stations	4	82.3	99.3	0.04
Number of acres planted	4	24.8	12.2	0.07
Annual production (1,000 cases)	3	43.7	59.9	—
Number of employees, peak season	4	18.0	9.88	0.9995
1,000 people within 60-minute drive	4	0.988	0.547	0.94
1,000 households within 60-minute drive	4	2.67	1.40	0.93

Predicting a Likely Range of Trips

When the number of sites used to determine a trip generation rate is small (i.e., below 30), one appropriate tool for quantifying the uncertainty that results from using the linear regression equation is a prediction interval, which is similar but not identical to a confidence interval. For a given value of the independent variable (such as number of employees), a prediction interval shows the expected range of the dependent variable (number of trips) with a certain probability.

The following expression is used to calculate a prediction interval (Hillier and Lieberman, 2001):

$$Y_c \pm \left(t_{0.025,n-2}\right)\sqrt{1+\frac{1}{n}+\frac{\left(X-\overline{X}\right)^2}{\sum_{i=1}^{n}\left(X_i-\overline{X}\right)^2}}\left(Y_{SE}\right)$$

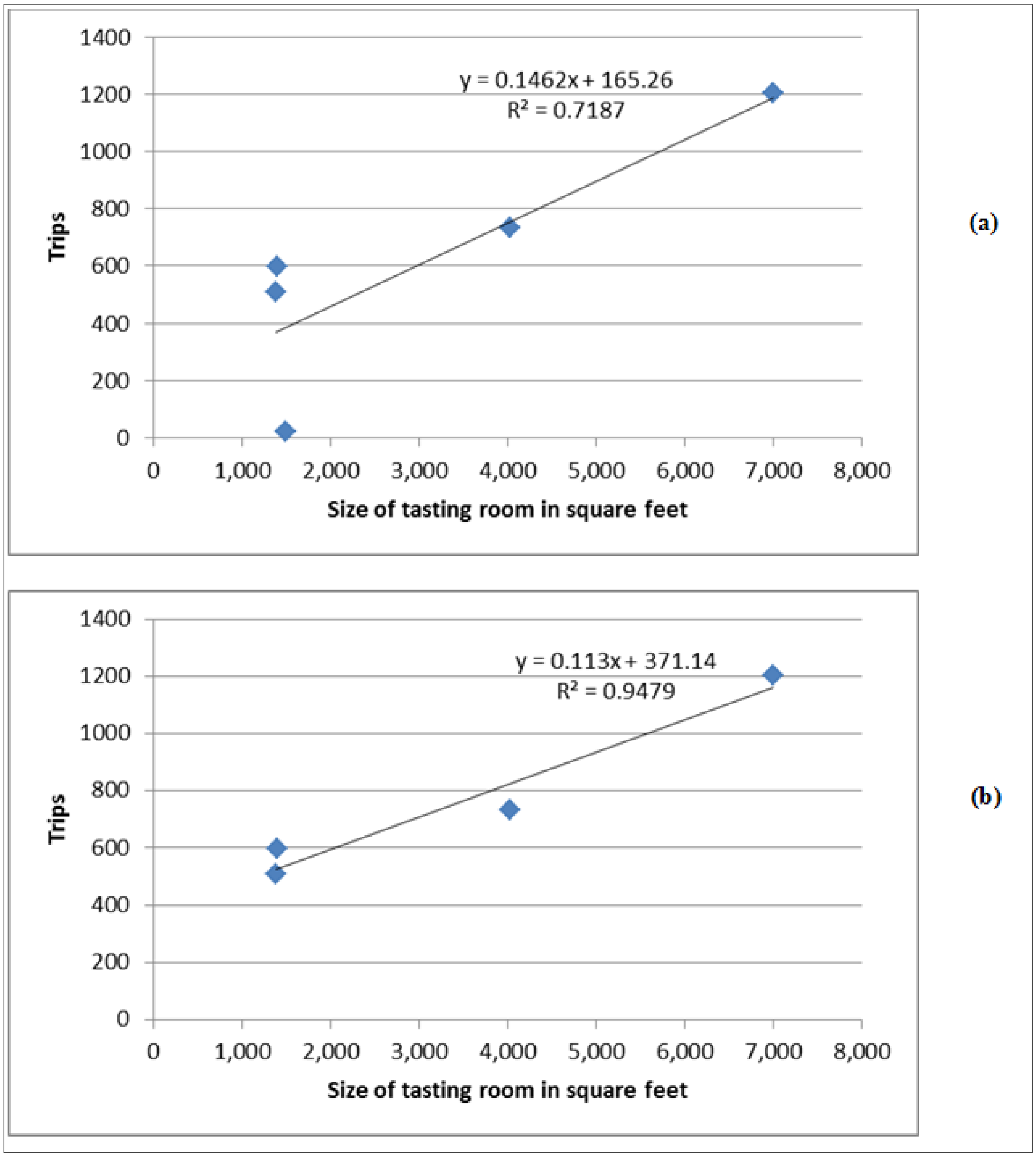


Figure 2. 24-Hour Saturday Scatter Plots for Trips vs. Size of Tasting Room: (a) including Site 5, (b) without Site 5

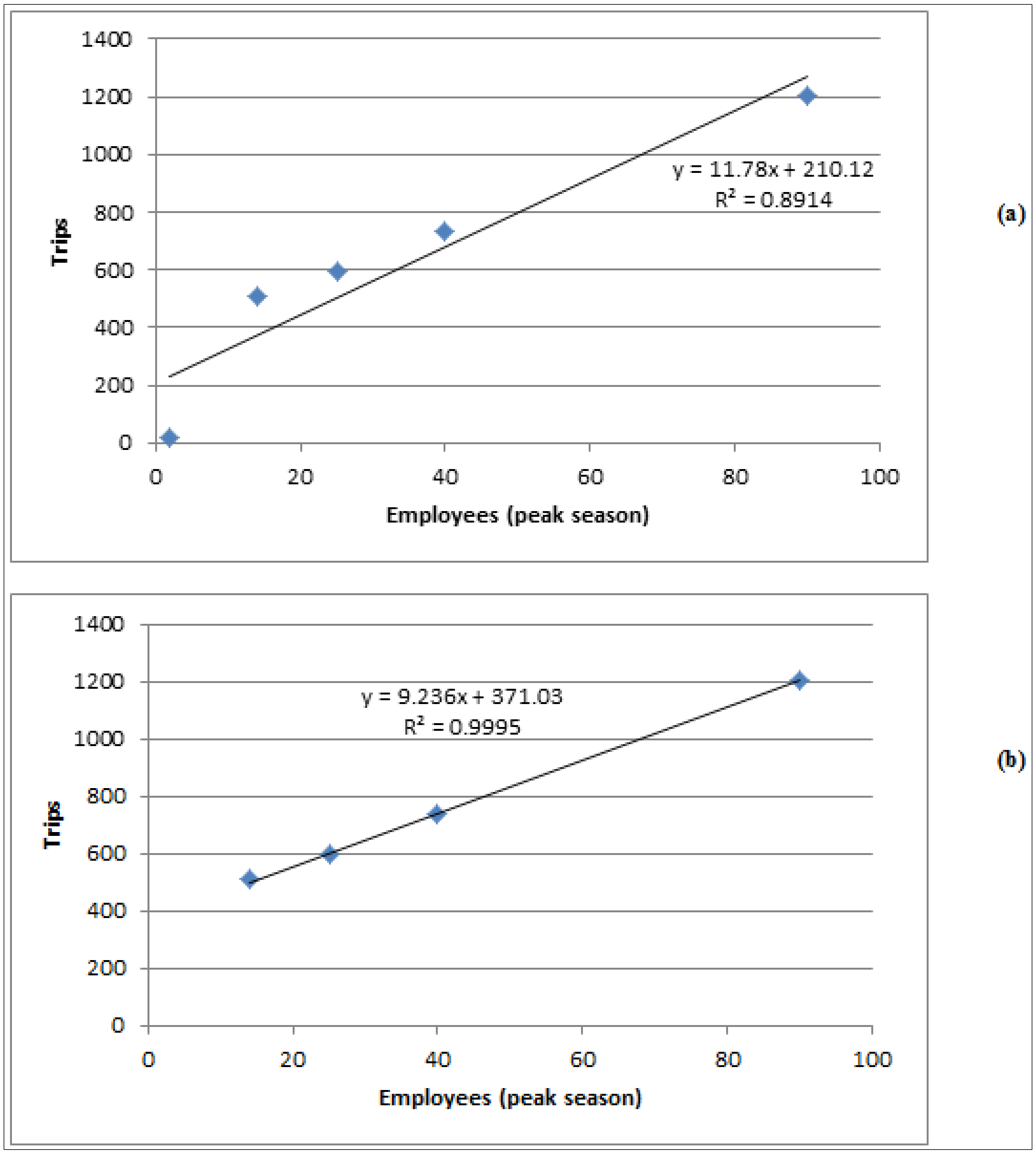


Figure 3. 24-hour Saturday Scatter Plots for Trips vs. Employees: (a) including Site 5, (b) without Site 5

where

Y_c = value of the dependent variable given X, computed with the linear regression equation

$t_{0.025,\, n-2}$ = a *t*-statistic for a prediction interval called the two-tailed inverse of the Student's *t*-distribution (which captures 95% of the observations)

n = sample size (number of sites used to calibrate the regression model)

X = given value of the independent variable used to compute Y_c

$\bar{X}$ = average value of the independent variable in the regression

X_i = each individual value of the independent variable

Y_{SE} = standard error of the Y estimate, which is calculated from the following equation:

$$Y_{SE} = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - y_i)^2}{n - p - 1}}$$

where

n = sample size (number of sites used to calibrate the regression model)

Y_i = value of the dependent variable for a given value of the independent variable, computed using the linear regression equation for each point in the data underlying the regression

y_i = actual value of the dependent variable for a given value of the independent variable from the data underlying the regression

p = number of independent variables.

The formula for a prediction interval was applied to the linear regression equation for Saturday trips by number of employees at peak season, excluding Site 5 (Figure 2d) with an arbitrarily chosen value of 60 employees, which falls between the data points that were collected. This yields the following values for each variable:

Y_c = 925 trips

$t_{0.025,n-2}$ = T.INV.2T(0.05,2) = 4.3

n = 4 sites

X = 60 employees (given)

$\bar{X}$ = 42.25

X_i values are 14, 25, 40, and 90

Y_{SE} = 8.59 based on Y_i values of 500, 602, 740, and 1,202; y_i values of 509, 596, 735, and 1,205; and p = 1.

The resulting range of predicted Saturday trips is 882 to 968. That is, for an agritourism use with 60 peak employees that is similar in other ways to those surveyed, there is a 95%

probability that it would see between 882 and 968 trips on a Saturday near peak season. The prediction interval concept could be applied to any of the other linear regression equations.

Testing the Fit for Census-Derived Variables

Figure 4 displays the data points and linear regression equations for the Census-derived variables, population within a 60-minute drive and households within a 60-minute drive, on a Saturday without Site 5. Despite relatively high values of R^2, these models do not necessarily demonstrate a good fit, because one of the data points is far away from the other three, which are clustered around a 60-minute population of 325,000 to 450,000. Although it may be the case that additional data collection would fill in other "dots along the line," it may also be the case that the data point outside the cluster represents an outlier that has undue influence on the regression equation. This remains true when Site 5 is included, but for the purposes of this example, it was excluded.

This example reflects only the Saturday equation for population within a 60-minute drive (Figure 4a), but similar results would be expected for households or Sunday data. Three of the four data points are clustered because the 60-minute populations for those sites are in the same range, between 325,000 and 450,000, whereas the fourth data point had a 60-minute population of nearly 2 million. This fourth point greatly influences the regression equation, one of the perils of having so few data points, and the equation no longer fits the data if that point is removed. Although one cannot make predictions using these regression equations, one can investigate the mean value of trips generated by agritourism sites that have a similar population within a 60-minute drive.

Interpreting the Mean Value of Trips Generated

Transportation and land development agencies may be interested in the mean value of trips generated by agritourism sites in order to compare them with other types of land development. For example, to what extent do agritourism sites tend to generate more trips than a coffee shop? In this regard, planners would want to know the extent to which the mean value of trips generated (based on this study) likely represents the mean value of trips generated from all sites comparable to these (in addition to those sites studied). This question can be answered by using inferential statistics, which use data from a sample to make inferences about the entire population.

With regard to the three sites, for example, that had a similar population within a 60-minute drive and that generated 509, 596, and 735 trips, respectively, the mean of these sites is 613 trips and the 95% confidence interval of this mean value can be calculated as

$$\text{Confidence interval} = \bar{Y} \pm \frac{TS}{\sqrt{n}}$$

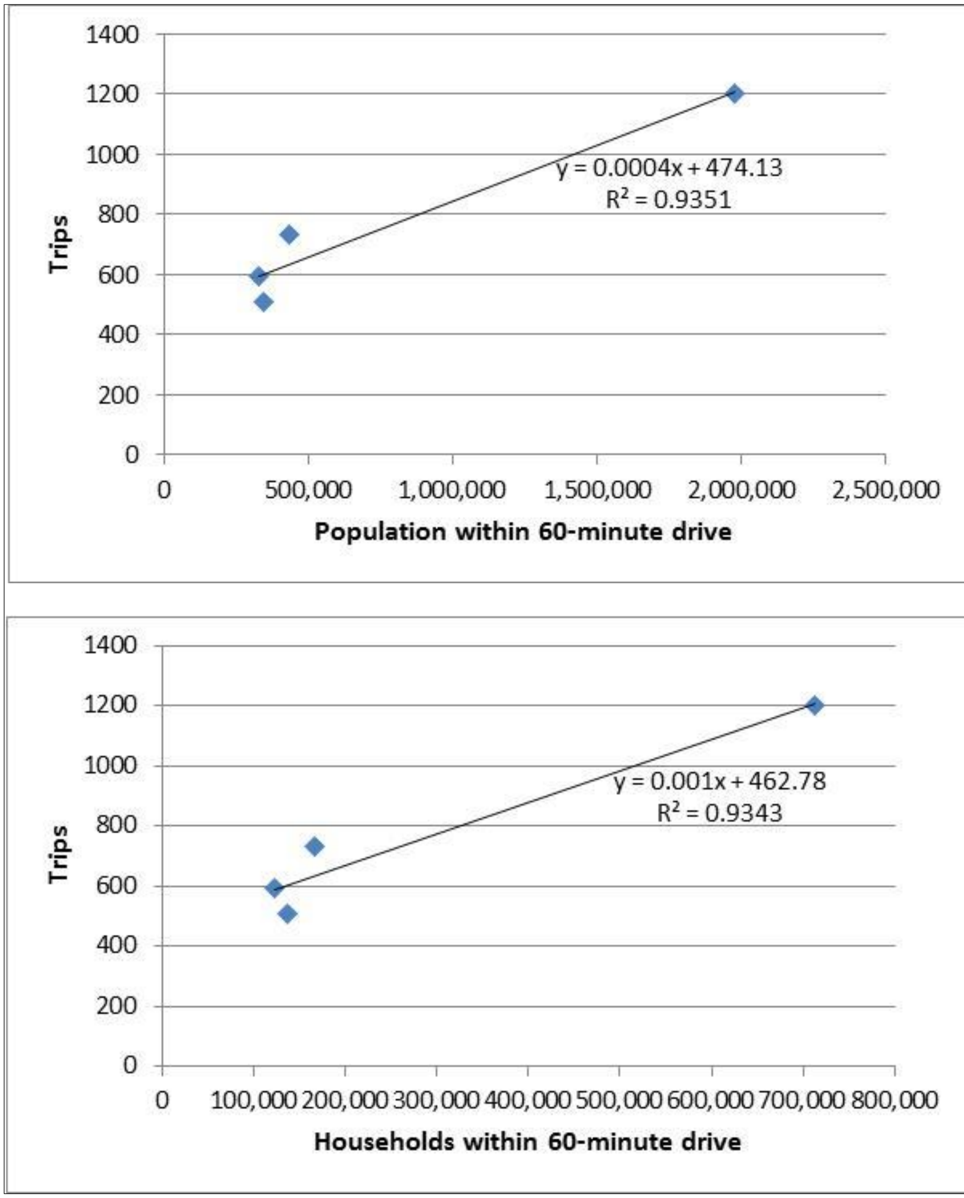
where

$\bar{Y}$ = mean value of trips for the three data points = 613 trips

T = *t*-statistic for a confidence interval, calculated in Excel as T.INV.2T(0.05,n-1)

S = standard deviation for the three data points, calculated in Excel as STDEV.S(509,596,735)

n = sample size = 3 sites.



(a)

(b)

Figure 4. 24-Hour Saturday Scatter Plots for Trips vs. (a) Population and (b) Households Within a 60-Minute Drive Without Site 5. Despite the R^2 values greater than 0.9, the regression equations shown are not good fits because of the clustering of some data points far away from another.

Montgomery (2001) explained that if many such intervals are created, where each one is drawn from a random sample of sites (with characteristics similar to those of the three observed in this study), 95% of the confidence intervals will include the true mean. The equation is applied as shown:

$$613 \pm \frac{4.30(114)}{\sqrt{3}} = 330 \text{ to } 897 \text{ trips}$$

Thus, the 95% confidence interval of the mean is 330 to 897 trips. This large interval reflects the small sample size. Although this is a broad range, it nonetheless remains useful if VDOT staff simply need to predict whether anticipated trips will exceed a threshold that is far outside this range, such as 50 trips per day.

Interpreting the Distribution of Trips Generated

A planner looking at a specific future agritourism site is less interested in the mean number of trips generated by all sites and more interested in what will happen at that particular site. Because only three sites that have similar characteristics were studied to develop the confidence interval noted, it is not possible to state precisely which distribution would be followed if all agritourism sites had been examined. However, because ITE (2012) presumed the normal distribution for a variety of other land uses, and because some have argued that the normal distribution can describe a variety of phenomena (for example, Véron and Rohrbasser, 2003), it is appropriate to consider inferences that could be drawn if the random component of the trips generated by a site does follow the normal distribution.

If it is the case that the number of trips for a Virginia agritourism site follows a normal distribution with a mean of 613 and a standard deviation of 114, one can determine the probability of a site generating a certain number of trips. For example, based on Figure 5, there is a 16% probability that a site will generate 500 trips or less but a 95% probability that a site will have 800 trips or less. Thus, if no other information were available, and if planners wanted to be able to be confident that a given site design would handle the number of trips generated by, say, 75% of all agritourism sites, then based on Figure 5 they would want the design to be able to accommodate up to about 700 trips.

Comparison of Average Rates

Another question of interest was whether the average trip rates calculated from the data were significantly different from ITE's rates for related land uses (ITE, 2012). This is illustrated here by a comparison of this study's average rate for trips per employee on a Saturday using the five-site chart (i.e., Figure 2c) and the same rate given by ITE for the specialty retail center land use. For each study, Table 10 shows the sample sizes and standard deviations that were used in this calculation.

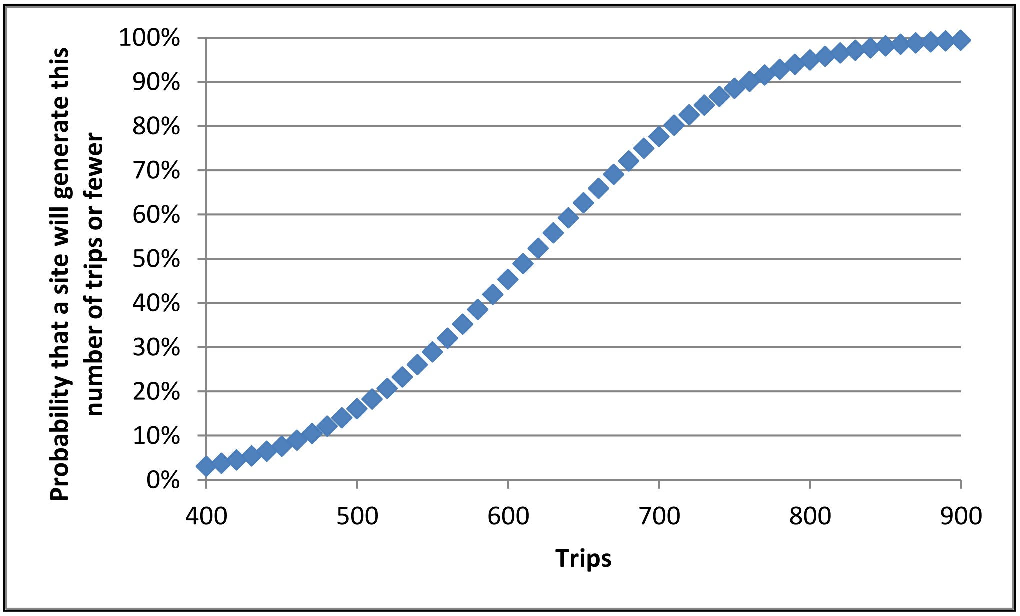


Figure 5. Cumulative Probability Distribution for Trip Generation. A normal distribution with a mean of 613 and a standard deviation of 114 is assumed.

Table 10. Data Used for Comparison of Average Rates From Two Studies

Study 1 (Current study): Virginia wineries (see Figure 2c)	
Sample size (n_1)	5
Standard deviation (S_1)	10.34
Average rate	17.92
Study 2: Specialty Retail Centers (ITE, 2012)	
Sample size (n_2)	3
Standard deviation (S_2)	4.94
Average rate	23.11

The following statistical calculations were used to compare the mean of two study samples. First, the standard deviation of the difference in means was calculated (Garber and Hoel, 2002):

$$Sd = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

where

S_1 and S_2 = standard deviations for Study 1 and Study 2, respectively
n_1 and n_2 = sample sizes for Study 1 and Study 2, respectively.

Sd was calculated to be 5.43.

Second, because the sample sizes were relatively small, a *t*-statistic was calculated based on a 95% confidence level and N, the sum of the sizes of the two samples (8 in this case). The *t*-statistic value was 2.45.

The absolute value of the difference between the two means was compared to the product of Sd and the *t*-statistic. If the absolute value of the difference between the two means (calculated to be 5.19) is greater than the product of Sd and the *t*-statistic (calculated to be 13.30), there is a significant difference between the means at the 95% confidence level.

Therefore, it cannot be concluded that there is a significant difference between these two means. That is, the average trip rate per employee on a Saturday in this study is not significantly different from the average trip rate per employee on a Saturday for ITE's specialty retail center land use. A similar result is obtained by comparing this study's average rate for trips per employee on a Sunday and the same rate given by ITE for the specialty retail center land use: at a 95% confidence level, it cannot be said that there is a significant difference between the average trip rates.

It should be noted that this result does not necessarily imply that it is appropriate to use the specialty retail center land use to evaluate agritourism land uses. This study had a small sample size of five, whereas the ITE rates were based on an even smaller sample size of three. The statistical result might differ with a larger sample of cases.

In fact, a different result was obtained when the weekday average rates were compared. For the five study sites, the average rate for weekday trips per peak employee was 5.36, whereas for ITE's three study sites for the specialty retail center land use, this rate was 22.36. Given the standard deviations for the two study samples, the absolute value of the difference between these means was higher than the product of Sd and the *t*-statistic, so at a 95% confidence level, it can be concluded that the average weekday trip rates per employee for agritourism land uses in this study are different from the weekday rates published by ITE for the specialty retail center land use.

DISCUSSION

For the limited sample of Virginia winery sites studied, variables that appear to have relatively high correlations with trips include square footage of tasting room, number of employees, and the Census-derived variables of population and households within a 60-minute drive.

Any discussion of these results must acknowledge the small sample size of four sites (or five, depending on the analysis presented). Given the hundreds of wineries and cideries in Virginia, the sample is likely not entirely representative. Extrapolating to other agritourism land uses such as farm markets or pick-your-own orchards would introduce additional uncertainty. In addition, the unique nature of agritourism land uses and the limited amount of information on independent variables that localities and VDOT may have at the review stage make it difficult to model these uses without complications. A final caveat is that many of the potential independent variables are in fact correlated (the most obvious example being the two Census-derived variables, which represent essentially the same measure), so any attempt to create a multivariate model would first need to address this multicollinearity.

The high standard deviation for the “size of parking area” variable is due to the small estimated parking area size for Site 4, which saw almost as many trips as Site 3 despite a significantly smaller formalized parking area. Although it may be possible to demonstrate correlation of trips with the parking variable given better data, it is equally possible that the nature of agritourism land uses—which often rely on informal grassy fields for peak season parking—may make it impractical, if not impossible, to collect objective data on parking supply.

Entrance Categories

Even a cursory examination of the results suggests that during relatively busy weekends in the fall, all surveyed sites with the exception of Site 5 (the primarily wholesale winery) had daily traffic volumes of well over 50 trips per day. Weekday traffic was lower but still above this amount. Because 50 trips per day is VDOT’s maximum threshold for a low volume commercial entrance, it appears that established retail-focused wineries/cideries similar to those studied would fall into either the moderate volume commercial entrance category or the commercial entrance category. The statistical analyses that were performed further support this determination.

A rural context is integral to the nature of agritourism land uses, and entrance design can support or detract from this context. It could be argued that VDOT’s standard commercial entrance design requirements detract from a rural context attributable in part to the pavement widths required (24 feet minimum, 30 feet minimum if not on a local street). In recognition of the integral nature of a rural context to the vitality of agritourism land uses and the Commonwealth’s ongoing interest in facilitating these businesses, VDOT could consider requiring a moderate volume commercial entrance for such land uses by default. Guidelines could be developed, or engineering judgment could be used, to determine whether a full-scale commercial entrance would be required instead. One factor in this decision could be information about the anticipated size and frequency of events.

Only one of the surveyed sites represented a non-retail focus, and its very low traffic volumes suggested that it would likely meet VDOT’s requirements for a low volume commercial entrance. It is not possible to generalize this determination for all wholesale-focused agritourism land uses based on this one data point, however.

Usefulness of Certain Variables

Although the “employees” variable may be driven by visitor volume rather than vice versa, its high degree of correlation with trips makes it an attractive independent variable. An estimate of the number of employees at peak season appears likely to relate to the number of trips a site will have. However, this variable is more prone to year-to-year adjustment than semi-permanent site characteristics such as square footage of a tasting room and factors not influenced by the site such as the Census-derived variables. A winery that opens with 10 peak season employees its first year may well have 20 the next year and 50 within a few years, but "10" would be the only number submitted for VDOT's review.

For wineries, square footage of a tasting room may be the most useful site-based variable for predicting a rough estimate of trip volume. Applicants are likely to have at least a good estimate for this quantity at the site plan stage, and it is unlikely to change frequently. However, the tasting room could be expanded as visitor volume grows (as occurred at one of the study sites shortly before data collection), and that expansion might or might not trigger notification to VDOT. Additional data collection could confirm whether a robust relationship with trip volumes exists.

Unlike the California studies cited in the literature review, this study did not find annual production to be a good predictor of trip volume. In fact, number of cases produced per year had one of the lowest correlations with trips of any independent variable, and when Site 5 was excluded, the relationship was in the opposite direction from what would be expected. This may be related to the generally smaller production volumes of Virginia wineries compared to those in Napa County; however, one-half of the 22 Napa County wineries used in developing that study's model had annual production volumes in the same range as those of the Virginia sites in this study (based on each case of wine containing 2.38 gallons).

Other Issues

Other variables not considered in this study could predict vehicle trips at agritourism land uses. One would be a measure of the amenities offered, such as outdoor recreational space or event space. This would not be captured by the variables examined in this study, such as interior space or acreage planted, and it is possible that additional recreational space or programming could affect trip generation rates by imparting a "destination" quality to the venue.

In addition, the predictive power of variables could be misleading. For example, the relationship between trips and population or households within a 60-minute drive of a site may not be linear if, say, people desire to visit certain remote destination wineries precisely because they are located away from developed areas.

The scope of this study did not include reviewing crash data near wineries or after events or addressing expansion of agritourism land uses over time, after an initial VDOT review. As noted earlier, when an agritourism land use begins operating, VDOT might be involved in the local approval process, but over the years, incremental expansion might not trigger re-review. This issue is not necessarily limited to agritourism land uses.

Other strategies could address traffic and safety concerns at other types of agritourism land uses, such as working with localities to allow for centralized farm markets with improved entrances rather than a farm stand in every unimproved driveway.

CONCLUSIONS

- *VDOT's practice of assuming low trip volumes for agritourism land uses in the absence of other data and the rural nature of the businesses may result in entrances that are undersized for the volume of traffic they carry, causing potential safety concerns for the traveling public.* During the peak season, only one site, which was not primarily a retail facility, had trip volumes under the threshold of 50 trips per day for a low volume commercial entrance. The four retail wineries/cideries studied had traffic volumes of 2 to 7 times this threshold on a weekday and 10 to 24 times the threshold on a Saturday.

- *The moderate volume commercial entrance category may be appropriate for agritourism land uses in most cases.* Although it appears that most mature agritourism land uses generate too much traffic to qualify for a low volume commercial entrance, there is interest at the state level in promoting and supporting agritourism land uses, to which a rural context and appearance are integral. Although exact trip volumes may be hard to predict, this entrance category might strike an appropriate balance between improving safety and maintaining a rural context.

- *Weekday peak hour volumes for the agritourism land use sites studied did not occur during the weekday peak hours of adjacent streets.* This was most pronounced for the morning peak hour for the adjacent streets, when the wineries studied all had volumes of 10 vehicles or less, representing less than 4% of their 24-hour average weekday volumes. Winery volumes were higher in the afternoon peak hour for the adjacent street but still lower than in the peak hour for site traffic.

- *Promising site-based variables for Virginia wineries include square footage of a tasting room and number of employees at peak season.* Square footage of a tasting room may be the most promising site-based variable, but additional data would be helpful to confirm this. Although subject to year-to-year fluctuations, an estimate of the number of employees at peak season was a strong correlate of the number of trips to a site. The availability of this information early in the site development process may vary by locality. Unlike previous studies from California, this study did not find annual production to be a good predictor of trip volume, suggesting that local differences may make it difficult to generalize the findings of this study to other states.

- *When no site-based variables are available other than location, Census-derived variables can provide some information.* In some cases, localities may not require applicants to provide site-based variables that VDOT could use to estimate trips. Although a larger or different sample might yield different regression equations, these variables can allow VDOT to assume a broad range of possible trip generation figures if a new site has levels of nearby population or households similar to those of the cluster of sites identified in this analysis.

- *Additional research could clarify the findings of this study.* Additional research could address topics outside the scope of this study, such as analyzing crash data near wineries or considering how to address the incremental expansion of agritourism land uses over time. Additional data collection from various types of well-established agritourism locations across Virginia could refine the results presented in this study, particularly at sites closer to large urbanized areas and with different types of agritourism land uses, such as farm stands.

RECOMMENDATIONS

1. *VDOT's Office of Land Use should provide guidance to VDOT's transportation and land use directors indicating that retail-focused wineries can be assumed to generate well more than 50 vehicle trips per day at peak season.* When determinations about entrance permits are made, this assumption could affect what type of entrance is required and whether safety improvements such as turn lanes are warranted.

2. *VDOT's Office of Land Use should investigate possible adjustments to the traffic volume thresholds for the moderate volume commercial entrance category.* Although peak season trips for retail wineries might exceed this category's maximum threshold of 200 entrance vehicles per day, volumes might be much lower for most of the year. It could also be the case that a higher maximum threshold (such as 500 entrance vehicles per day; alternatively, a threshold could be expressed as a percentage of the adjacent street's daily volume) is appropriate for this entrance type.

BENEFITS AND IMPLEMENTATION

Benefits

The main benefit of this study is in providing guidance that was requested by VDOT's transportation and land use directors. This guidance will allow them to make the soundest decisions possible when reviewing entrance permit requests, which in turn could provide benefits for traveler safety.

The result of a sound decision would be an entrance type that aligns with actual vehicle volumes. The benefit expected from such a decision is the *avoided cost* of making a suboptimal decision (in this case, about an entrance category). Additional benefits to travelers could be realized if safety improvements such as turn lanes are justified and installed.

One example of a decision that is less than ideal would be requiring an entrance that is "too small" or underdesigned; i.e., actual traffic volumes are higher than it can handle. The costs to travelers associated with this error could be expressed in terms of time cost (delays) and crash costs, both resulting from queueing vehicles trying to enter and exit a site driveway that cannot handle the volume. These increasingly frequent conflicts potentially increase the costs attributable to delay and crashes. In addition, costs to proprietors could include (1) property damage attributable to trucks or other large vehicles that cannot navigate the entrance without leaving the pavement and (2) being required to upgrade (reconstruct) the entrance because of safety, use, or maintenance concerns.

On the other hand, requiring an entrance that is "too large" for actual traffic volumes would also be an imperfect decision. This study recommends considering the moderate volume commercial entrance category rather than the commercial entrance category partly because of the much higher construction costs of a commercial entrance to the proprietor. (There could also be aesthetic costs attributed to unnecessary damage to the rural context.) These costs would be based on the design requirements for the three categories of commercial entrances; some of these requirements are highlighted in Table 11, which is based on Figures 4-1, 4-9, and 4-15 in Appendix F of VDOT's *Road Design Manual* (VDOT, 2005).

Table 11. Selected VDOT Design Requirements for Commercial Entrance Categories

Dimensional Requirement	Low Volume Commercial Entrance	Moderate Volume Commercial Entrance	Commercial Entrance
Surfaced width	12-24 ft	18-30 ft	30-40 ft
Graded width	16 ft minimum	Surfaced width	Surfaced width
Entrance radius	20 ft minimum	25 ft minimum	25-50 ft; 12 by 48 ft taper
Distance from edge of pavement that surface requirements apply	Greater of right-of-way line or length disturbed	25ft minimum	35 ft minimum

Implementation

To implement Recommendation 1, VDOT's Office of Land Use plans to provide guidance in the form of a presentation to VDOT's transportation and land use directors at one of the group's quarterly meetings and to post guidance on InsideVDOT. This will be accomplished in Fiscal Year 2017.

To implement Recommendation 2, VDOT's Office of Land Use plans to meet with staff of VDOT's Location and Design Division and initiate a review of the standards and restrictions associated with the "moderate volume commercial entrance" design within a month of the publication of this study.

Additional implementation activities have already been completed. Trip generation results from this study were presented in 2015 at VDOT's Land Development Summit and at the American Planning Association's Virginia Conference. In 2015 and 2016, the researcher submitted the trip generation data from this study to ITE, which considers all new land use data it receives. Coupled with potential future data submittals for wineries in other states, these data could prove useful. Although this study's sample size of four or five sites was small, ITE presents data even for land uses with very few data points. ITE's Traffic Engineering Senior Director responded to the submittals and stated that the data would be considered for inclusion in an upcoming update of the *ITE Manual.*

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REFERENCES

Aguayo, V. Traffic Impact Study for the Ceja Farms Project. Memorandum. Whitlock & Weinberger Transportation, Inc., Santa Rosa, CA, August 25, 2011. http://votma.org/files/traffic_study.pdf. Accessed August 13, 2013.

Arnold, E.D. *Trip Generation at Special Sites.* Virginia Highway & Transportation Research Council, Charlottesville, 1984. http://ntl.bts.gov/lib/36000/36500/36554/84-R23.pdf. Accessed September 23, 2013.

Belvedere Plantation. Plan Your Visit to Belvedere Plantation. 2013. http://belvedereplantation.com/planVisit.php. Accessed September 16, 2013.

Code of Virginia § 3.2-300-302. http://leg1.state.va.us/lis.htm. Accessed September 23, 2013.

Code of Virginia §§ 3.2-6400. http://leg1.state.va.us/lis.htm. Accessed February 24, 2015.

Code of Virginia §§ 15.2-2288.3, 15.2-2288.3.1, and 15.2-2288.6. http://leg1.state.va.us/lis.htm. Accessed February 24, 2015.

Code of Virginia §§ 33.2-223, 33.2-240, 33.2-241, and 33.2-245. http://leg1.state.va.us/lis.htm. Accessed February 24, 2015.

County of San Diego, Department of Planning and Land Use. *Draft Final Environmental Impact Report, Part 3 Appendices.* San Diego, CA, July 14, 2010. http://www.sandiegocounty.gov/content/dam/sdc/pds/advance/winery/wineryeirpart3appendices071410.pdf. Accessed March 20, 2015.

Federal Highway Administration. *Traffic Monitoring Guide.* 2013. http://www.fhwa.dot.gov/policyinformation/tmguide/. Accessed March 13, 2015.

Fehr & Peers. *Napa County Travel Behavior Study: Draft Survey Results and Data Analysis Report.* Walnut Creek, CA, 2014. http://d3n8a8pro7vhmx.cloudfront.net/shwindow/mailings/113/attachments/original/Nap a_Travel_Study_Final_Report_12-8-14_w_Figures.docx.pdf?1419621712. Accessed March 9, 2015.

Garber, N.J., and Hoel, L.A. *Traffic and Highway Engineering,* 3rd ed. Brooks/Cole, Pacific Grove, CA, 2002.

Hillier, F.S., and Lieberman, G.J. *Introduction to Operations Research,* 7th ed. McGraw-Hill, New York, 2001.

Institute of Transportation Engineers. *Trip Generation Handbook*, 2nd ed. Washington, DC, 2004.

Institute of Transportation Engineers. *Trip Generation Manual*, 9th ed. Washington, DC, 2012.

Johnson, J.M. *VDOT Traffic Impact Statement, Buffalo Mountain Brewery.* Anderson & Associates, Inc., Blacksburg, VA, 2013.

Kottage, J. Email to M. Enright [with additional handwritten notes], October 26, 1998.

Lee, R., Miller, J., Maiss, R., Campbell, M., Shafizadeh, K., Niemeier, D., Handy, S., and Parker, T. Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies. In *California Smart-Growth Trip Generation Rates Study, Final Report, Appendix D.* Institute of Transportation Studies, University of California, Davis, 2012. http://downloads.ice.ucdavis.edu/ultrans/smartgrowthtripgen/Appendix_D_Evaluation_of_Available_Methods.pdf. Accessed October 16, 2015.

Miles, J.C., and Smith, N. *Models of Recreational Traffic in Rural Areas*. TRRL Supp. Rpt. 301. Transport and Road Research Laboratory, Wokingham, Berkshire, UK, 1977.

Montgomery, D.C. *Introduction to Statistical Quality Control,* 4th ed. John Wiley & Sons, Inc., New York, 2001.

Pack, J.D., and Johnson, K.J. *Riverside County Wine Country Model Development Memo.* Fehr & Peers, Riverside, CA, September 19, 2011.

SB 430 Farm brewery licenses, limited; Board of Alcoholic Beverage Control may grant to certain breweries. 2014. http://leg1.state.va.us/cgi-bin/legp504.exe?141+sum+SB430. Accessed March 14, 2014.

Tubbs, S. Albemarle Adopts New Rules to Allow Events at Farms. *Charlottesville Tomorrow,* Thursday, November 13, 2014a. http://www.cvilletomorrow.org/news/article/19514-albemarle-farm-events/. Accessed June 11, 2015.

Tubbs, S. Albemarle Must Allow Events at Farms and Farm Breweries. *Charlottesville Tomorrow,* Wednesday, March 26, 2014b.

http://www.cvilletomorrow.org/news/article/17604-albemarle-farm-events/. Accessed June 11, 2015.

Véron, J., and Rohrbasser, J.M. Wilhelm Lexis: The Normal Length of Life as an Expression of the "Nature of Things." *Population*, Vol. 58, No. 3, 2003, pp. 303-322.

Virginia Department of Transportation. *Road Design Manual.* 2005. http://www.virginiadot.org/business/locdes/rdmanual-index.asp. Accessed March 13, 2015.

Virginia Economic Development Partnership. Wineries. August 2011. http://gis.yesvirginia.org/datasets/484f797a1abb4b6296bedf823895e609_15. Accessed April 16, 2015.

Virginia Office of the Governor. Governor McAuliffe Announces Virginia Wine Sales Reach New Record High in Fiscal Year 2014. 2014. https://governor.virginia.gov/newsroom/newsarticle?articleId=6574. Accessed February 24, 2015.

Weldon Cooper Center for Public Service, Demographics Research Group. Population Estimates for Virginia, Its Counties & Its Cities. 2015. http://www.coopercenter.org/demographics/virginia-population-estimates. Accessed June 10, 2015.

APPENDIX A

INVITATION SCRIPT AND SITE QUESTIONNAIRE

Invitation Script

[An earlier version of the script was used for some initial contacts. After some negative feedback was received by the researcher, the script was revised, as seen here, and reviewed by a survey expert.]

If a human answers: Hi, my name is [name]. I'm with the research division of VDOT, the Virginia Department of Transportation. We are studying the variation in traffic patterns at seasonal businesses such as wineries and pick-your-own orchards. We know that everyday traffic volumes for [farm wineries/ pick-your-own orchards] can vary greatly by time of the year. If you have five minutes, I'd like to see if you could answer nine questions for me.

> [If busy:] I'd be glad to call another time, come talk in person, or send the questions by email.
>
> [If yes:] These questions ask about characteristics of [business name]. We chose your business because it is seen as a well-established example of a [farm winery/pick-your-own orchard]. We are interested in this information to find out whether any of these characteristics can predict traffic volumes.

If a machine answers: Hi, my name is [name]. I'm with the research division of the Virginia Department of Transportation. We are studying the variation in traffic patterns at seasonal businesses such as wineries and pick-your-own orchards. We know that everyday traffic volumes for [farm wineries/ pick-your-own orchards] can vary greatly by time of the year. If you have five minutes, I'd like to set up a time to ask you nine questions about this subject. When you get a chance, please give me a call at [callback number]. I'll also send this in an email so you can reply to that instead. Thanks!

Site Questionnaire

[The following questions were asked of each site. Some questions, as noted, were different for pick-your-own orchards than for wineries.]

1. Number of parking spaces (some respondents noted that spaces were not marked but provided the number of cars they could accommodate)
2. Size of parking area (including unmarked spaces; square feet or acres)
3. Size (square feet of total interior space)
4. *Wineries only:* Size (square feet of tasting room)
5. *Wineries only:* Number of tasting stations
6. Number of acres planted with grapes (*wineries*) or fruit trees (*orchards*)

7. Annual production (*wineries:* gallons or cases) (*orchards:* bushels of fruit)
8. Expected number of employees at peak season
9. *Orchards only:* Number of cash registers at peak operation
10. Thinking about daily business and excluding events, what is your guess as to the 5th busiest day of the year for your facility?
11. Would you be willing to give VDOT permission to place temporary counting equipment across your entry drive to count vehicles entering and exiting? (We would be glad to share the data with you.)

APPENDIX B

GIS ANALYSIS PROCEDURE

What follows is step-by-step ArcGIS guidance for VDOT staff to produce a planning-level estimate of the population within a 1-hour drive of a given site. If this population is within the range of 325,000 to 450,000 people, a likely trip generation range can be stated.

This example was written using ArcMap version 10.0 and assumes basic familiarity with GIS. (As of September 2015, version 10.0 was the standard installation for VDOT employees, who had the option to upgrade to version 10.2.1 if needed, but version 10.2.1 was not compatible with some planning-related VDOT software.)

First, a word about data management. In some cases, performing GIS computations over the VDOT network may be impractical because of the amount of data being transferred. It is preferable to perform the analysis with the data saved locally, i.e., on your computer's hard drive. However, it is still important to save your data on the network in case something happens to your hard drive. Therefore, it is suggested that you save your data as follows:

- *"Pristine" data:* save on the network. The data you begin with, such as downloaded Census files, should be stored on the network in its original form and copied locally for analysis.
- *Working data:* save on your hard drive. This includes any intermediate files produced as part of the analysis as well as copies of pristine and final data.
- *Final data:* save on the network. You will create it locally and then copy it to the network for storage.

1) **Add data to a GIS map.** These data are required in order to complete the service area analysis and include a street network and the location of the site of interest. (Census population data will be added later.)

   a) Add a *street network dataset.* For areas not within 1 hour of another state, a Virginia-only file will suffice. For this study, a network dataset called *streets.rsx* that was included with ArcGIS base data was used and is available from the author. (Esri's StreetMap Premium service would also work, although its World Street Map service would not. The Virginia Geographic Information Network [VGIN] provides official street data for Virginia that may be suitable for areas in central Virginia. The VGIN street data do not work for areas near other states, since it does not contain street information for adjacent states. Data files of VDOT roads have the same limitation and the additional problem that city- and town-owned streets are not included.)

      i) Add data to a new map by clicking the *Add Data* button (), navigating to the folder where the file is saved, selecting it, and clicking *Add*. Be sure to select the network dataset, which would have an icon similar to this:  . In the dialog box that opens, click *Yes* to add the network dataset and all its source feature classes to the map.

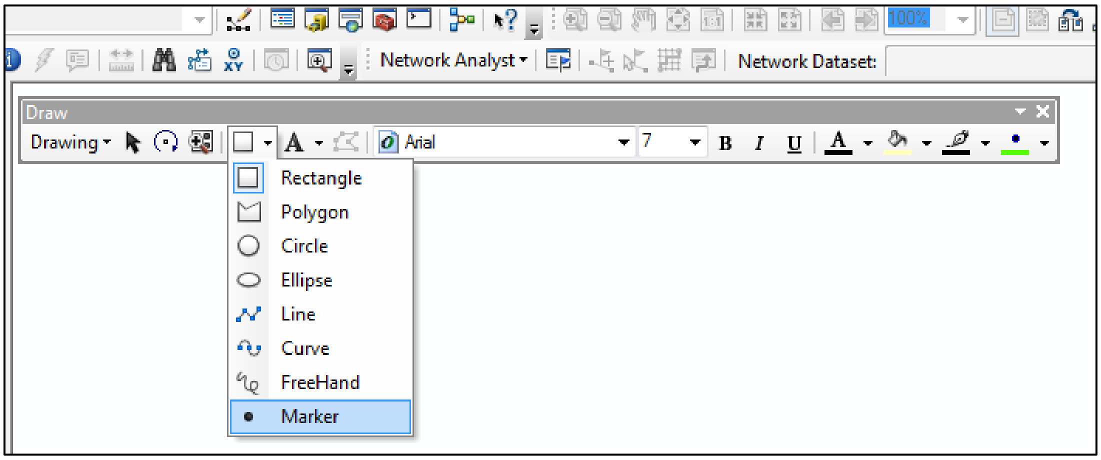
ii) Zoom roughly to the area of interest to minimize drawing time, especially if using a U.S.-wide street file.

b) Create a point layer containing the *location of the agritourism site* to be studied.

i) If you are able to locate the site by zooming in on the streets, the easiest way to do this is by using the *Draw* toolbar. Turn it on from the *Customize* menu.

ii) Zoom in on the site location so that you will be able to click and place a dot with sufficient precision.

iii) In the *Draw* toolbar, click the drop-down arrow next to the rectangle and select *Marker*.



iv) Click on the map to create a point at the site location. You can move it around with the toolbar's Select arrow if needed.

v) On the *Draw* toolbar, click *Drawing*, then *Convert Graphics to Features*. In the dialog box, choose where to save the file, name it, check the box next to *Automatically delete graphics after conversion*, and click *OK*. In the subsequent dialog box, click *Yes* to add the data to the map. Close the *Draw* toolbar if desired and save your map.

2) **Configure the Network Analyst environment and create a new service area analysis layer.** (The instructions in Steps 2 through 5 are based on the *Network Analysis Workflow* page within ArcGIS 10 Help and other pages linked from that page.)

a) General setup and preparation:

i) Ensure that the Network Analyst extension is enabled: In the *Customize* menu, choose *Extensions* and ensure that the Network Analyst box is checked. Click *Close*.

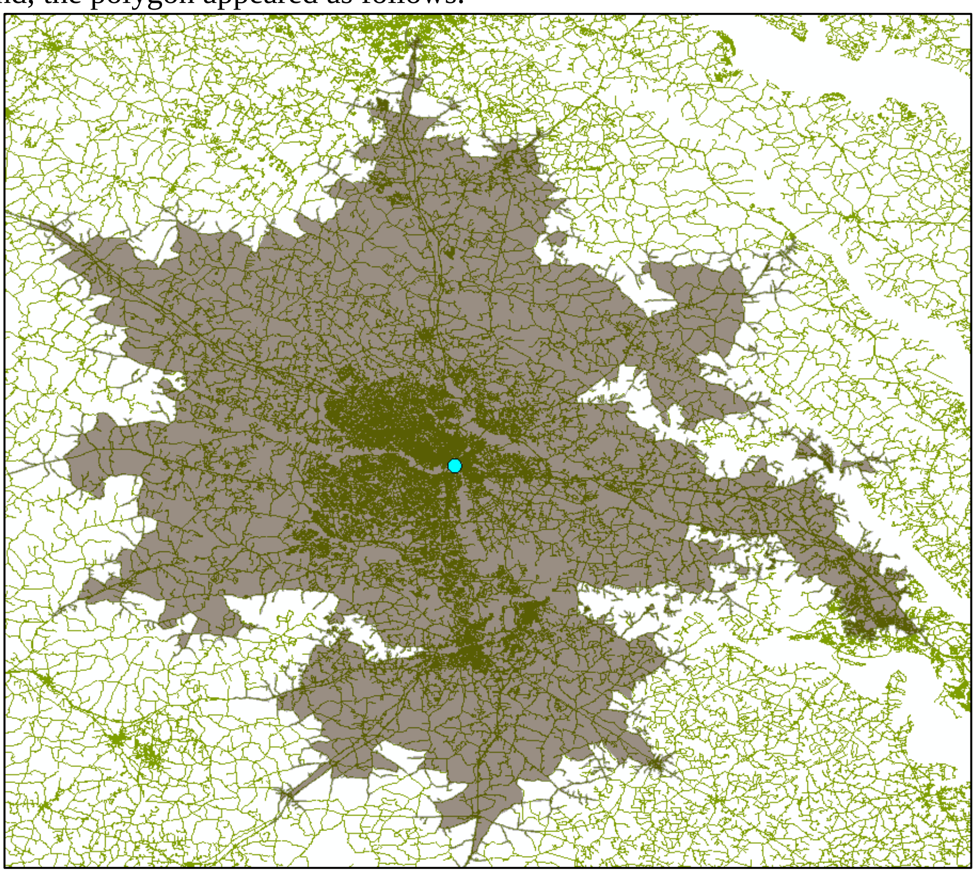
ii) Display the Network Analyst toolbar and Network Analyst window: In the *Customize* menu, choose *Toolbars* and ensure that the Network Analyst toolbar is checked.

b) Create a new service area analysis layer: On the Network Analyst toolbar, the name of your network dataset should appear next to Network Dataset (*streets*, in this case). On the Network Analyst toolbar, click *Network Analyst*, then *New Service Area*.

3) **Load the point layer that represents the site location as a network analysis object.**
   a) In the Network Analyst toolbar, click the icon to display the Network Analyst window.
   b) In the Network Analyst window, right-click on *Facilities (0)* and select *Load Locations.*
   c) In the dialog box that opens, the point layer you created in Step 1(b) should be shown next to *Load From*. Leave other options as they are and click *OK*.

4) **Configure the service area analysis layer to compute the area within a 60-minute drive of the study site.**
   a) In the Network Analyst window, click the icon to display the Layer Properties dialog box. (In ArcMap version 10.2, this dialog box is called Service Area Properties.)
   b) Click the *Analysis Settings* tab.
   c) Next to Impedance, *Time (Minutes)* should be shown.
   d) Next to Default Breaks, type *60*.
   e) Under Restrictions, *OneWay* and *Non-routeable Segments* should be checked.
   f) Click *OK*.

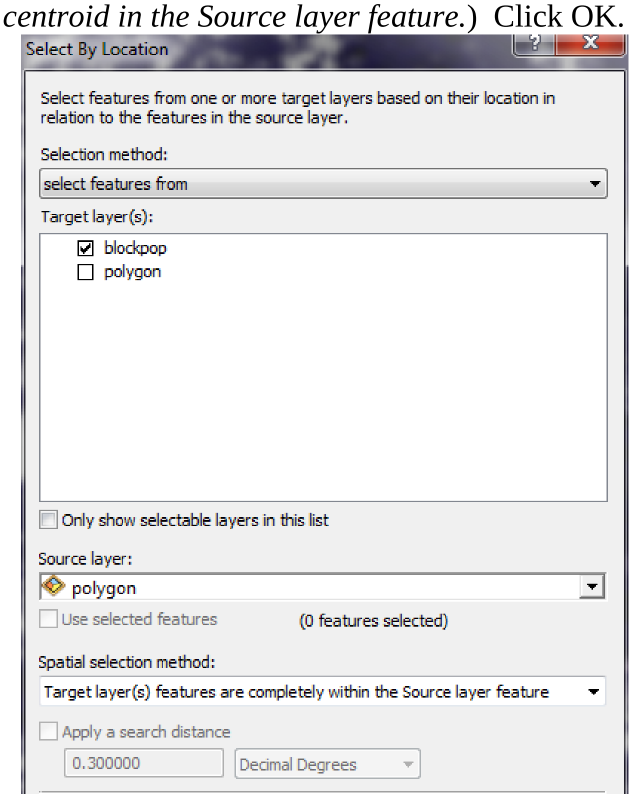
5) **Perform the analysis.** On the Network Analyst toolbar, click the Solve button ( ). The analysis may take some time. When it completes, if everything worked properly, you will see a new polygon representing the 60-minute drive time from your study site. (To see it, you may need to right-click the *Polygons* icon shown in the Table of Contents and click *Zoom to Layer*.) For a dummy site location at the VDOT headquarters in downtown Richmond, the polygon appeared as follows.



6) **Export the service area polygon so you can open it in the future if needed without redoing the analysis.**
   a) In the Table of Contents window, right-click on the polygon within the service area layer, select *Data*, and select *Export Data.*
   b) Select the option to use the same projection as the data frame. Choose a location to save the new file and click OK. After the file is created, click OK to add it to the map; you can turn off or remove the service area and streets layers to reduce drawing time.

7) **Add a file containing population data by census block, optionally clipped to Virginia and contiguous states to reduce computation time.** Click the *Add Data* button (), navigating to the folder where the file is saved, selecting it, and clicking *Add*. For this study, a dataset called *blockpop.sdc* that was included with ArcGIS base data was used and is available from the author. It displays a point at the centroid of each census block and contains population data. Data could instead be downloaded from the National Historical Geographic Information System (NHGIS) or U.S. Census websites (e.g., TIGER files); in those cases, it might be necessary to download both a table of population data and a block geography file and join the two for analysis.

8) **Select the blocks with centroids that are within the polygon.**
   a) In the *Selection* menu, click *Select by Location.*
   b) Configure the window that opens to select features from your block centroid layer (the target layer) that are completely within the polygon (the source layer), as shown. (Note that if you are using a polygon block file with actual boundaries rather than centroids, you may want to choose a different spatial selection method, such as *Target layer(s) features have their centroid in the Source layer feature*.) Click OK.



(Note that blocks with some area within the service area polygon but a centroid outside it will be excluded and blocks with some area outside the polygon but a centroid inside it will be included. A more precise approximation could be obtained by calculating the area of each census block that is within the service area polygon and multiplying the block's population by that proportion, as was done by Schneider et al. (2012) for block groups.)

9) **Export the selected blocks to a new file so you can open it in the future if needed without redoing the analysis.**
   a) Right-click on the block file, select *Data*, and select *Export Data.*
   b) Ensure that the option to export only *Selected features* is selected. Choose a location to save the new file and click OK. After the file is created, click OK to add it to the map; you can turn off or remove the block file.

10) **Open the attribute table of your new blocks file.** Select the column representing population by clicking its heading. Right-click the heading and select *Statistics*. The total population for the collection of blocks is shown next to *Sum*; make a note of it.

As noted in the "Testing the Fit for Census-Derived Variables" section of this report, the small sample size of this study led to regression equations with questionable fit for Census-derived variables. Estimating trip generation based on population within a 1-hour drive of the site is possible only when the population falls in the range of 325,000 to 450,000, the range of 1-hour populations surrounding three of the sites in this study. If your newly calculated total population is in that range, the 95% confidence interval of 330 to 897 Saturday trips provides a likely range of trips. Assuming the normal distribution for the unpredictable component of trips, Figure 5 would give the probability of a site generating a certain number of trips.

If your newly calculated total population is outside that range, additional data collection from sites with 1-hour populations between 450,000 and 2 million would be necessary in order to validate or adjust a regression equation for this variable.

Reference

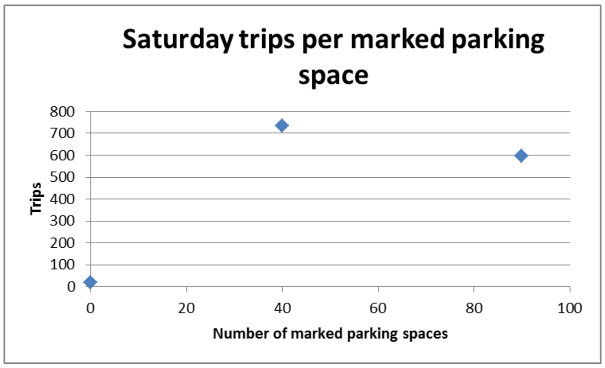
Schneider, R.J., Shafizadeh, K., and Handy, S. *Methodology for Adjusting ITE Trip Generation Estimates for Smart-Growth Projects, California Smart-Growth Trip Generation Rates Study, Final Report, Appendix F*. 2012. http://downloads.ice.ucdavis.edu/ultrans/smartgrowthtripgen/Appendix_F_Adjustment_Method.pdf. Accessed October 15, 2015.

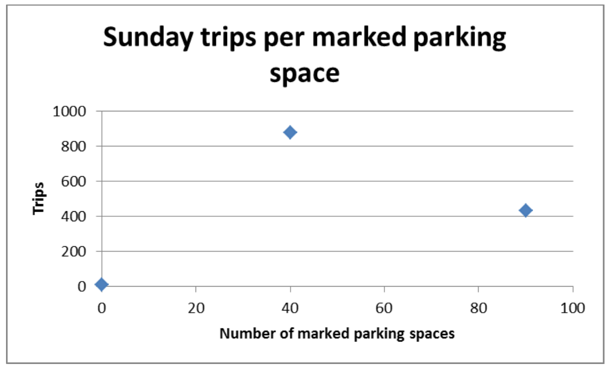
APPENDIX C

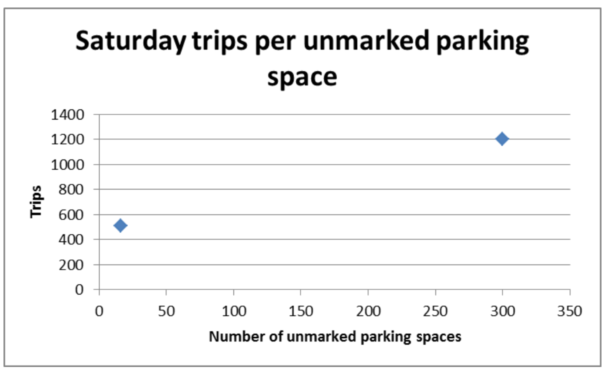
CORRELATION CHARTS

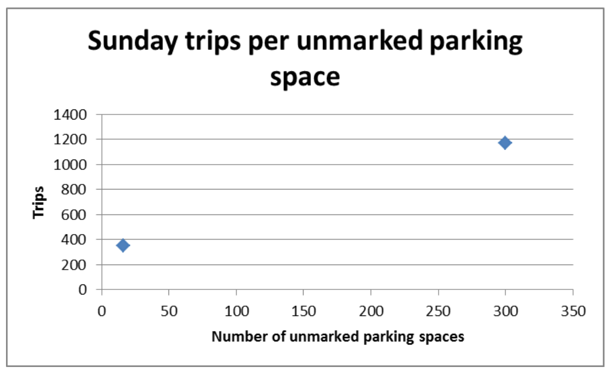
The charts in this appendix display 24-hour Saturday and Sunday scatter plots for each variable analyzed in this study, first for the analysis of all five sites and then again excluding Site 5 because of its different context. For variables with at least four data points, a linear regression equation is shown along with its R^2 value.

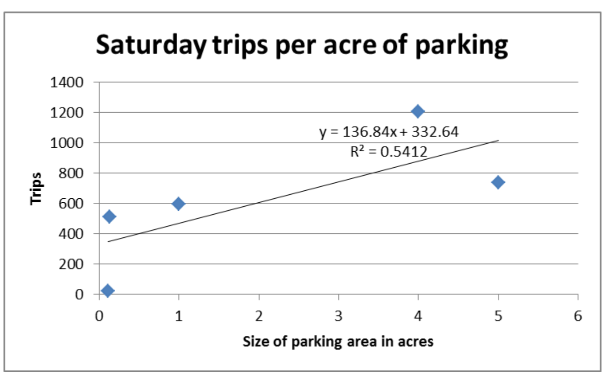
Charts Including Site 5

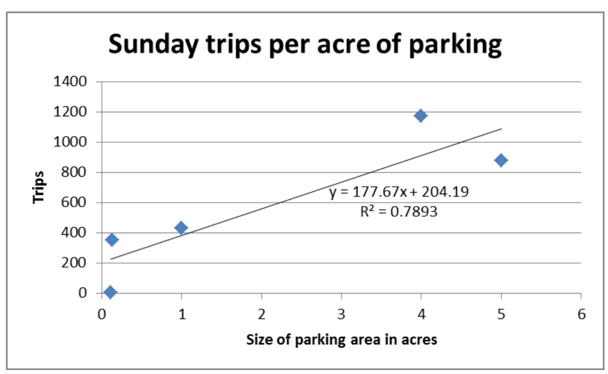


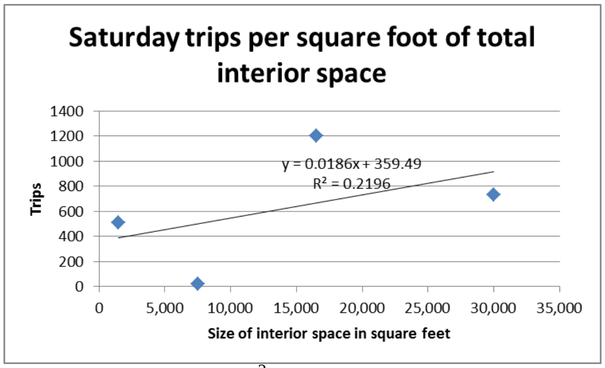


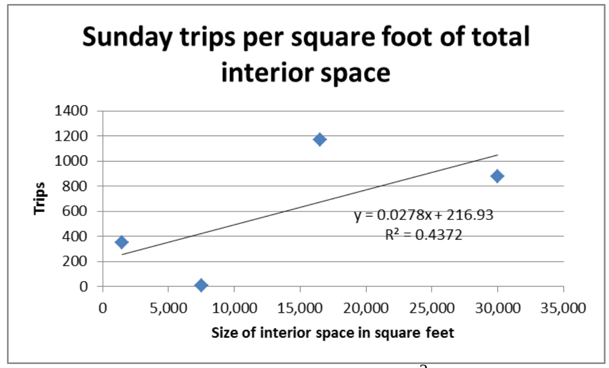




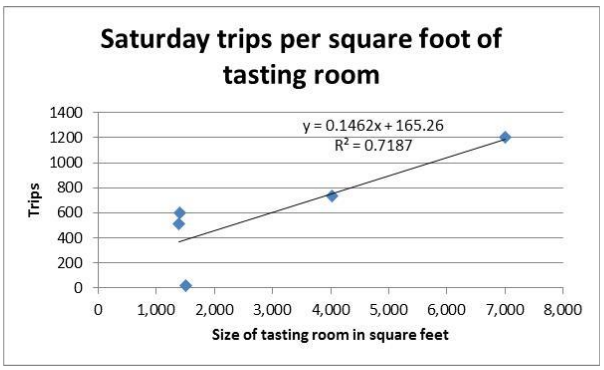


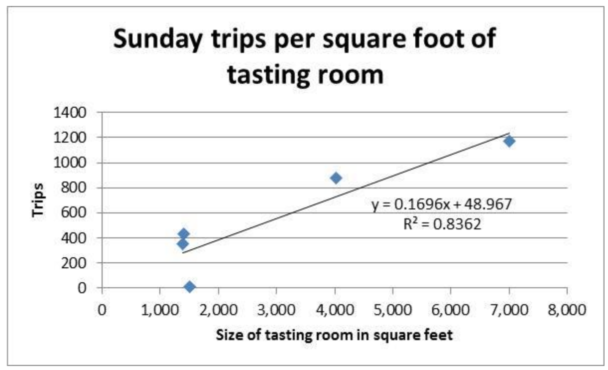


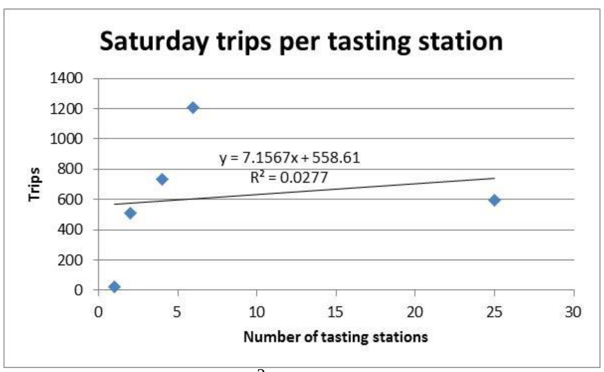


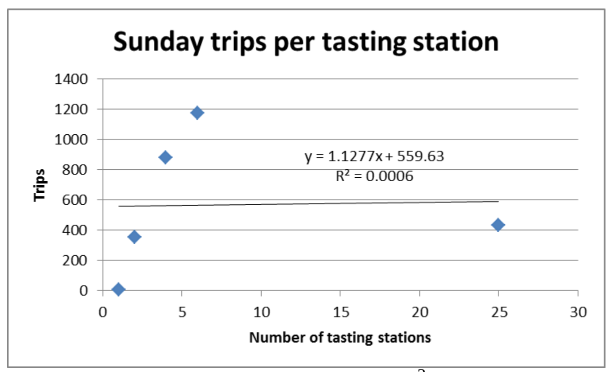


Note: Because of low R^2 values, ITE's conditions would prohibit display of the equations and R^2 values.

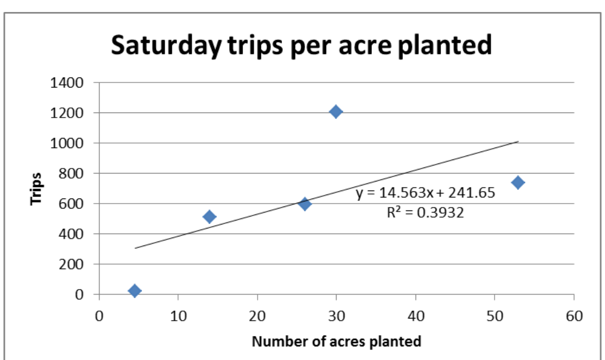


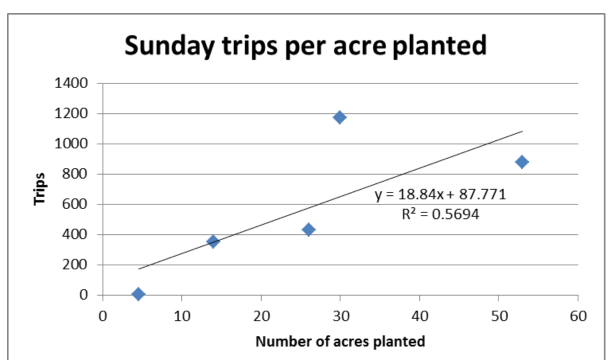




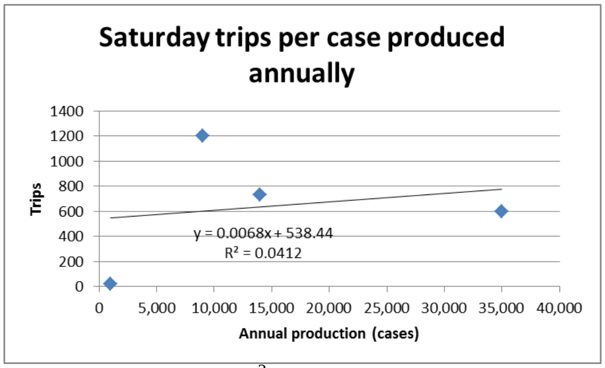


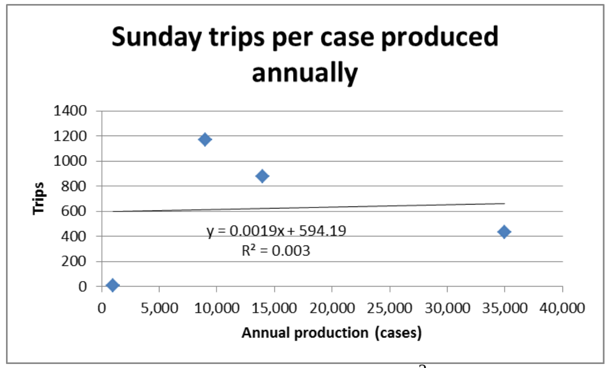
Note: Because of low R^2 values, ITE's conditions would prohibit display of the equations and R^2 values.



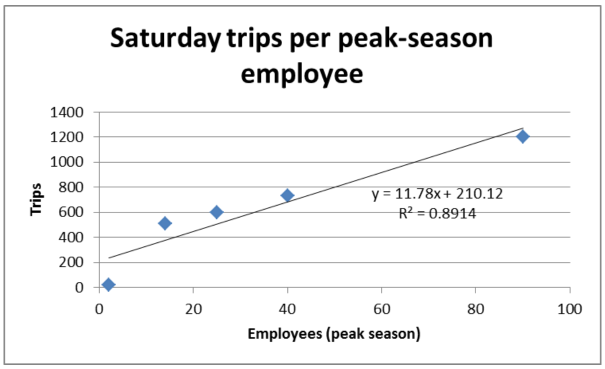


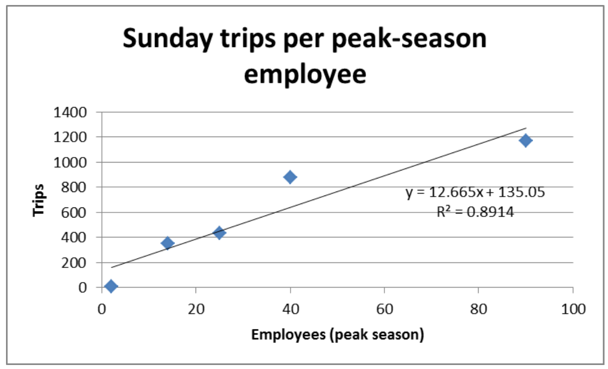
Note: Because of a low R^2 value, ITE's conditions would prohibit display of the Saturday equation and R^2.

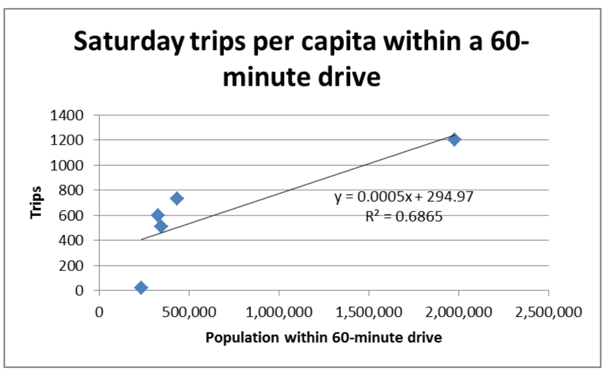


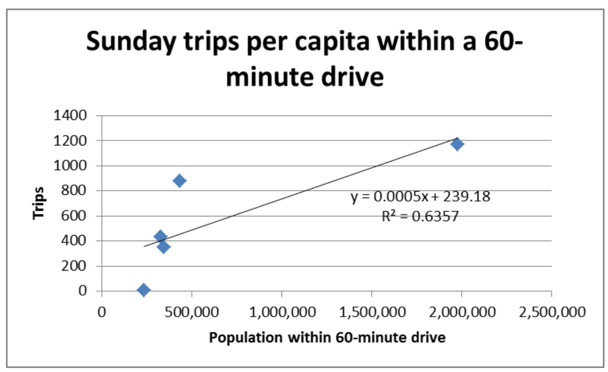


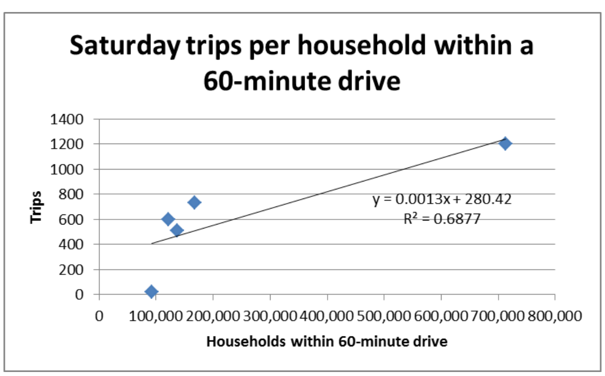
Note: Because of low R^2 values, ITE's conditions would prohibit display of the equations and R^2 values.

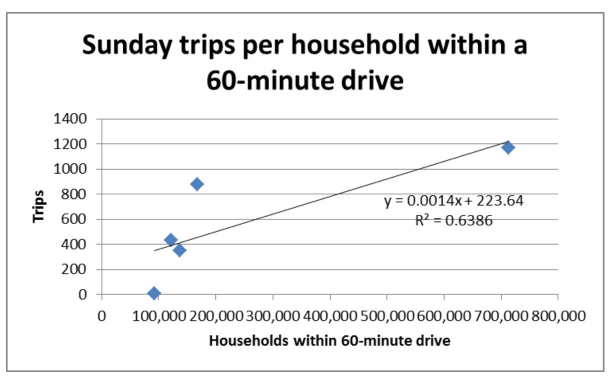




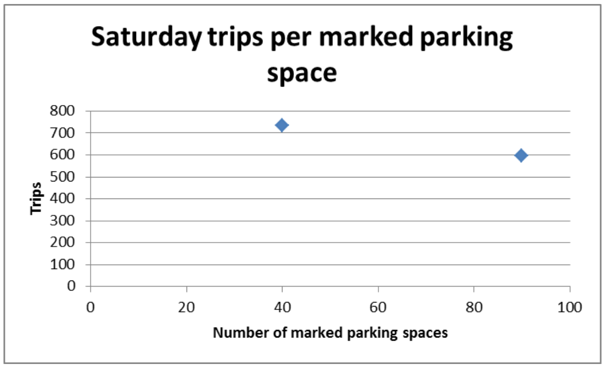


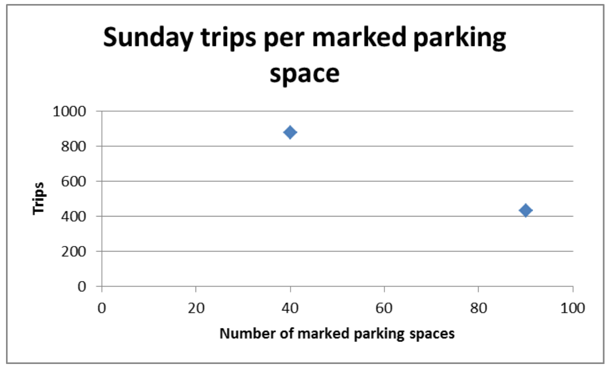


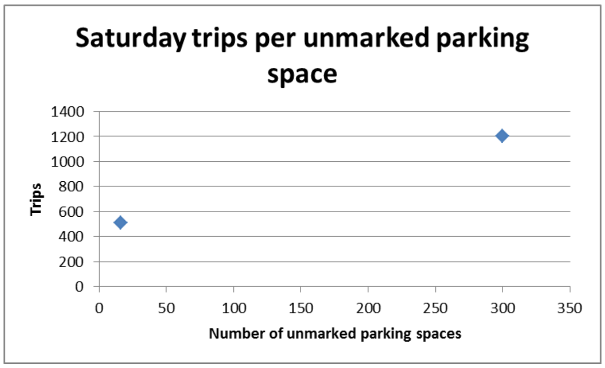


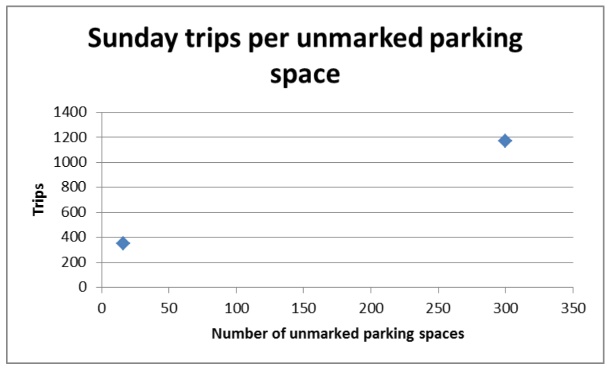


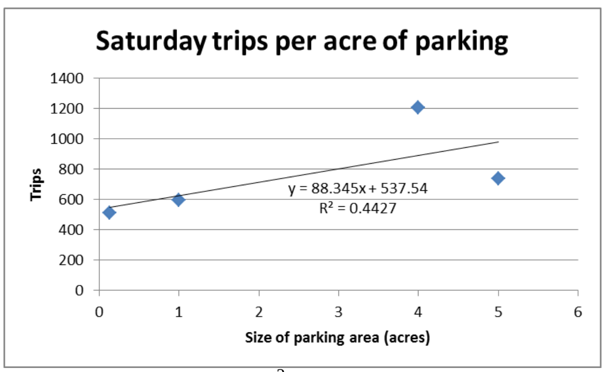
Charts Excluding Site 5

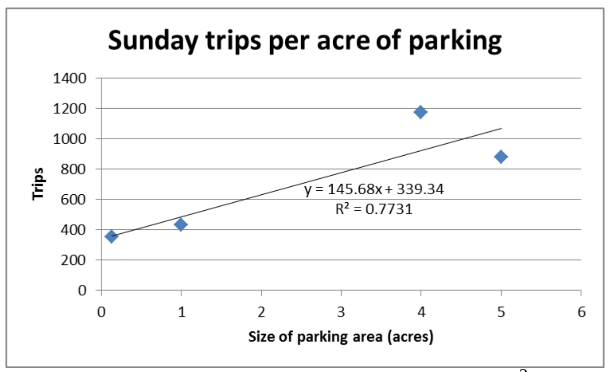




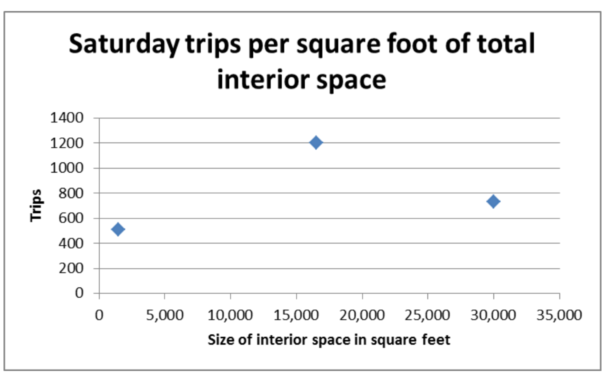


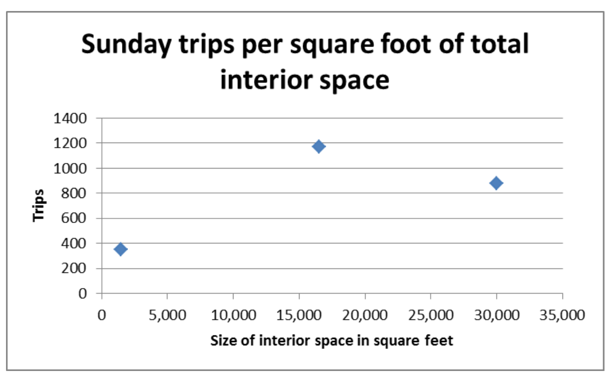


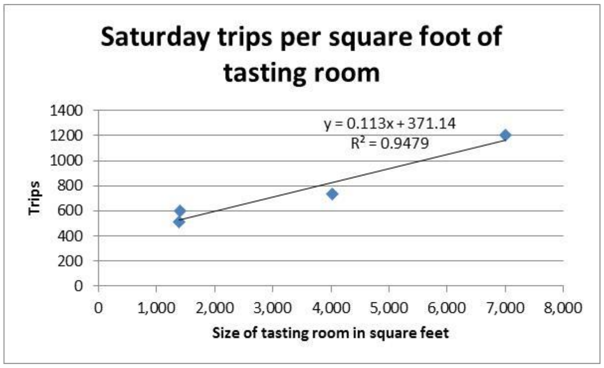


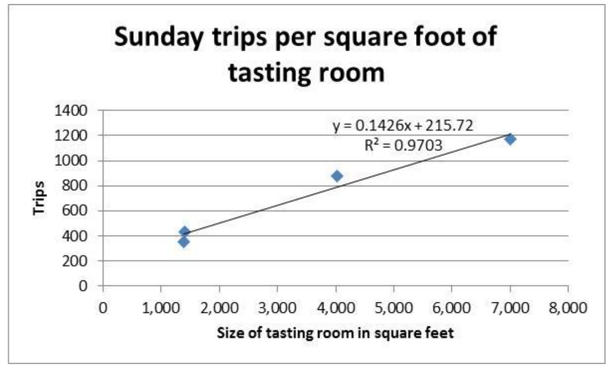


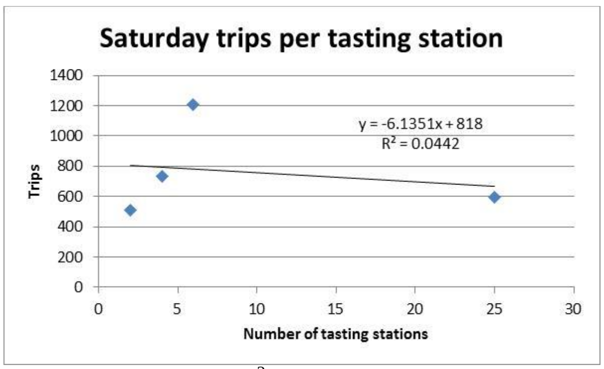
Note: Because of a low R^2 value, ITE's conditions would prohibit display of the Saturday equation and R^2.

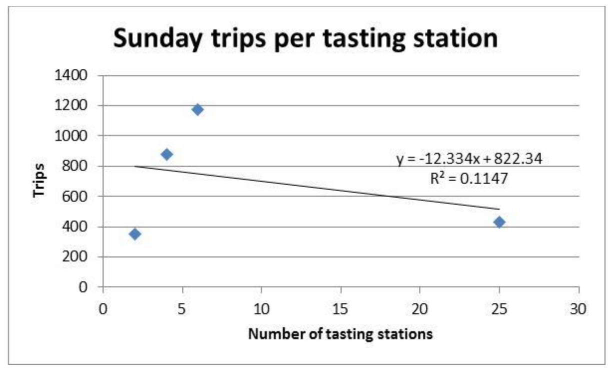




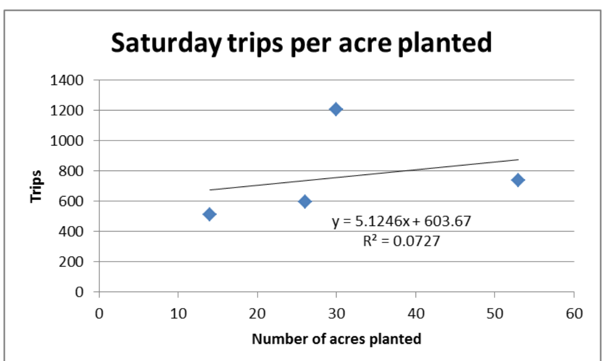


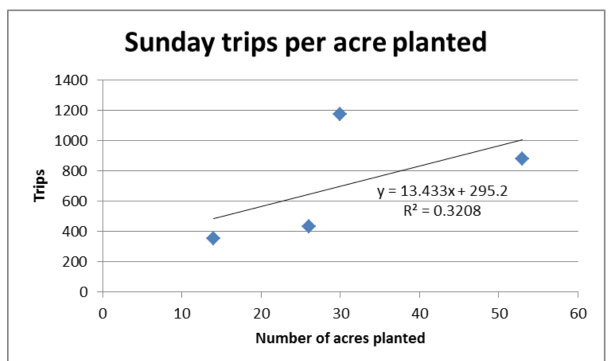




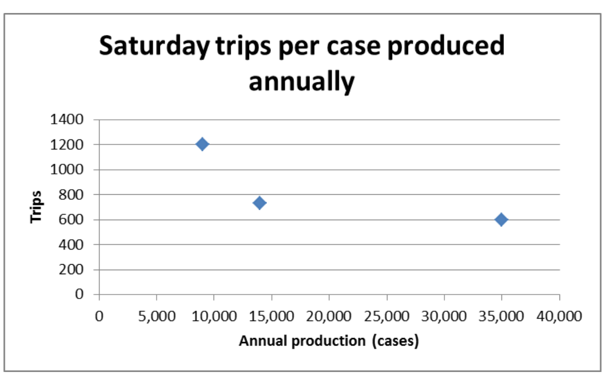


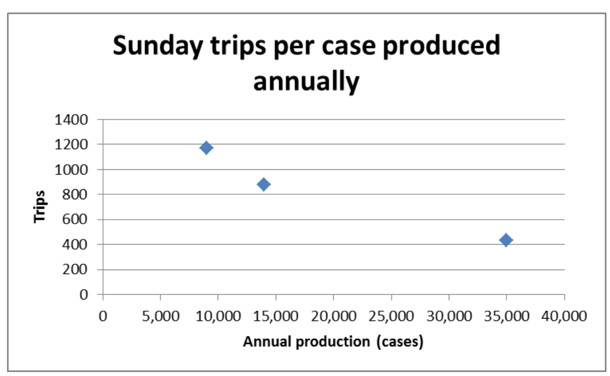
Note: Because of low R^2 values and the downward slopes of the trend lines, ITE’s conditions would prohibit display of the equations and R^2 values.

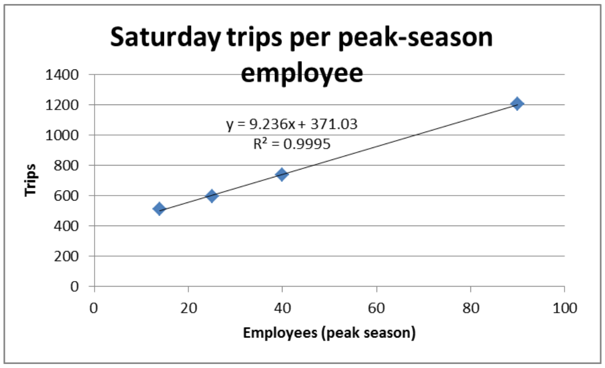


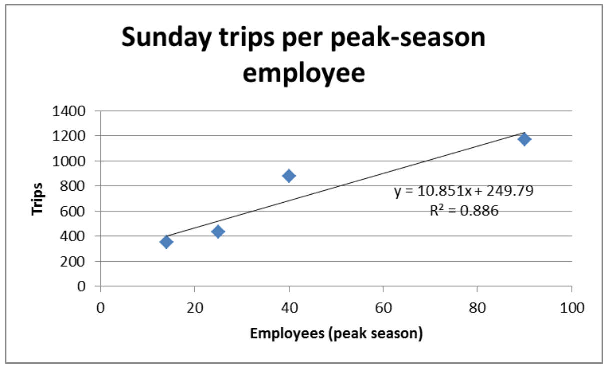


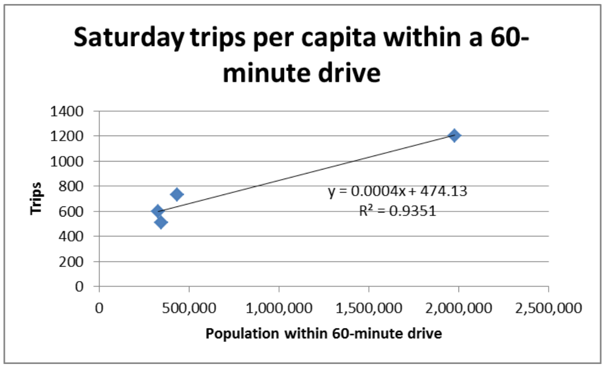
Note: Because of low R^2 values, ITE’s conditions would prohibit display of the equations and R^2 values.

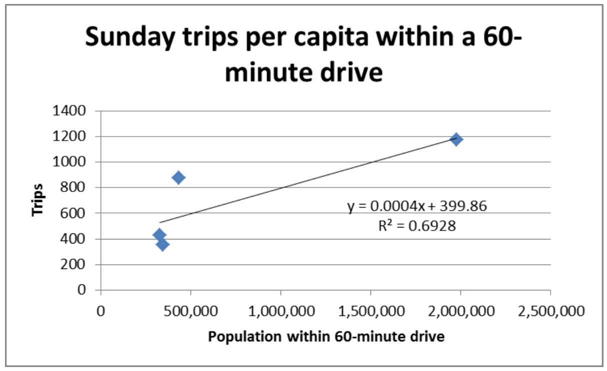


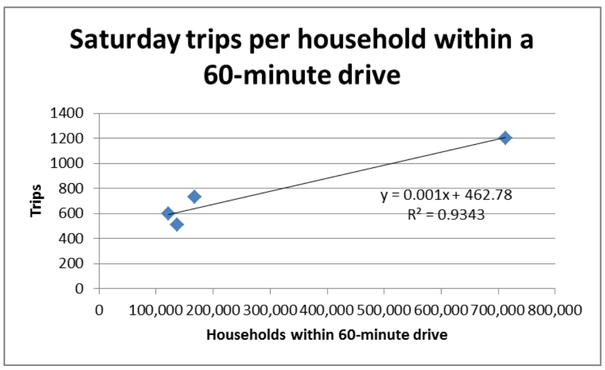


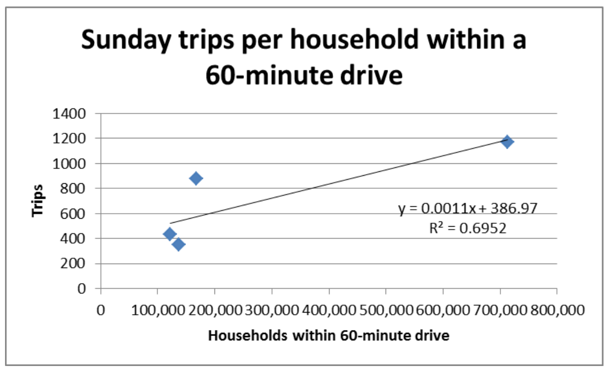

Saturday trips per peak-season employee
y = 9.236x + 371.03
R² = 0.9995
Trips
Employees (peak season)


Sunday trips per peak-season employee
y = 10.851x + 249.79
R² = 0.886
Trips
Employees (peak season)


Saturday trips per capita within a 60-minute drive
y = 0.0004x + 474.13
R² = 0.9351
Trips
Population within 60-minute drive


Sunday trips per capita within a 60-minute drive
y = 0.0004x + 399.86
R² = 0.6928
Trips
Population within 60-minute drive


Saturday trips per household within a 60-minute drive
y = 0.001x + 462.78
R² = 0.9343
Trips
Households within 60-minute drive


Sunday trips per household within a 60-minute drive
y = 0.0011x + 386.97
R² = 0.6952
Trips
Households within 60-minute drive