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The impact of a new casino on the motor vehicle crash patterns in suburban Maryland

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ABSTRACT

Background: Many states have legalized casino gambling, and casinos create increased vehicle traffic, but the strength of the association between casino construction and vehicle crashes is unknown.
Methods: Retrospective analyses of motor vehicle crashes (MVCs) occurring within Anne Arundel County, Maryland (2010–2014) were conducted. The ratio of crashes within one mile of the casino's location after it was opened were compared to the ratio occurring in the same area before it was opened to determine how the incidence of MVCs near the casino changed with time. Logistic regression was used to determine how crash characteristics may have influenced the incidence of MVCs near the casino after it opened.
Results: 101,860 persons were involved in 43,328 MVCs in Anne Arundel County during the study period; 29,476 (68.0 %) had an at-fault driver ≥21 years of age and complete data. MVCs proximal to the casino occurred most commonly during the day (N = 421, 76.6 %) and involved drivers < 40 years of age (N = 366, 66.6 %) and male (N = 316, 57.4 %). After adjustment for impairment and day of the week, there was a significant association with crashes close to the casino after it opened ($OR_{Adjusted}$ = 1.23, 95 % CI: 1.04–1.46, p = 0.02). Crashes occurring close to the casino, after it opened, involved drivers < 40 years of age (OR = 1.74, 95 % CI:1.45–2.08) and occurred on weekends (OR = 1.39, 95 %CI:1.15–1.67).
Conclusions: In this single-site study the opening of a casino was associated with an increase in crashes nearby. The generalizability of this finding should be confirmed with analysis of MVC data near other gambling venues.

1. Introduction

There were 2.4 million injuries and 35,485 fatalities related to motor vehicle collisions (MVCs) in the United States in 2015 (National Center for Statistics and Analysis, 2016), resulting in an estimated $242 billion in annual costs (Blincoe et al., 2010). A variety of external and behavioral factors contribute to the occurrence of motor vehicle crashes and their resultant injuries, including impaired drivers, speeding and aggressive behavior, and lack of seat belt use (Maryland Highway Safety Office, 2020; Soderstrom et al., 1990; Cooper, 1997; Cooper, 1994; Underwood et al., 1999).

Over the last decade, six casinos have been opened in Maryland following expansion of legalized casino gambling by the state legislature (Maryland Lottrey, 2012). The construction of a casino in a community requires changes to the local infrastructure to accommodate the expected increase of visitors from both the local neighborhoods and

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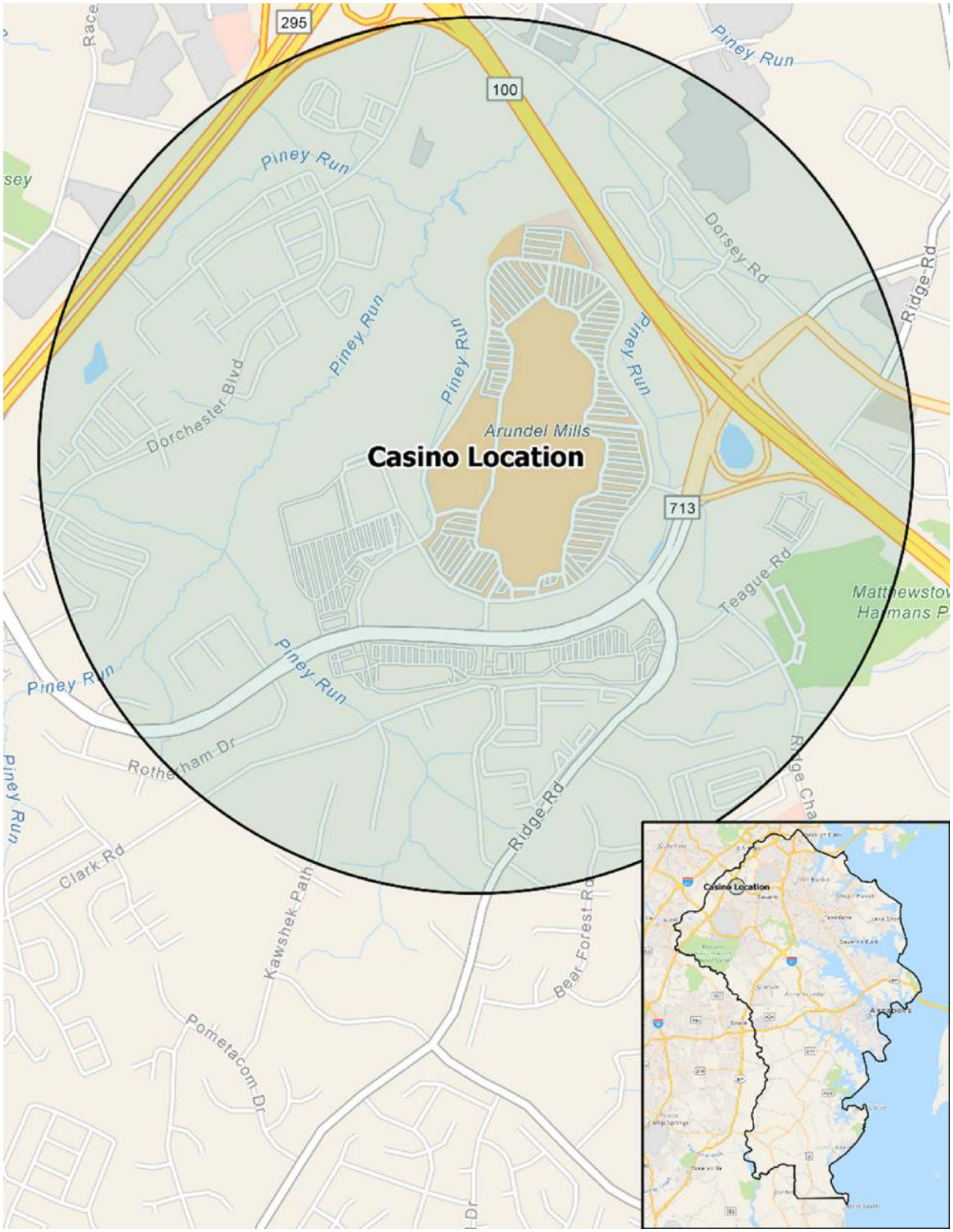

Fig. 1. One-mile radius shown around the casino location and surrounding roadways. Insert shows surrounding Anne Arundel County boundary in Maryland state.

surrounding areas (Cotti and Walker, 2010). The opening of a casino, and its associated businesses, has been shown to change motor vehicle traffic patterns, create increases in pedestrian and vehicle traffic, and increase the density of alcohol licenses in that specific area (McGowan, 2013; Walker, 2013).

Cotti and Walker examined Fatal Analysis Reporting System (FARS) data and found that the magnitude and direction of a casino's effect on impaired driving fatalities is dependent upon the size and population

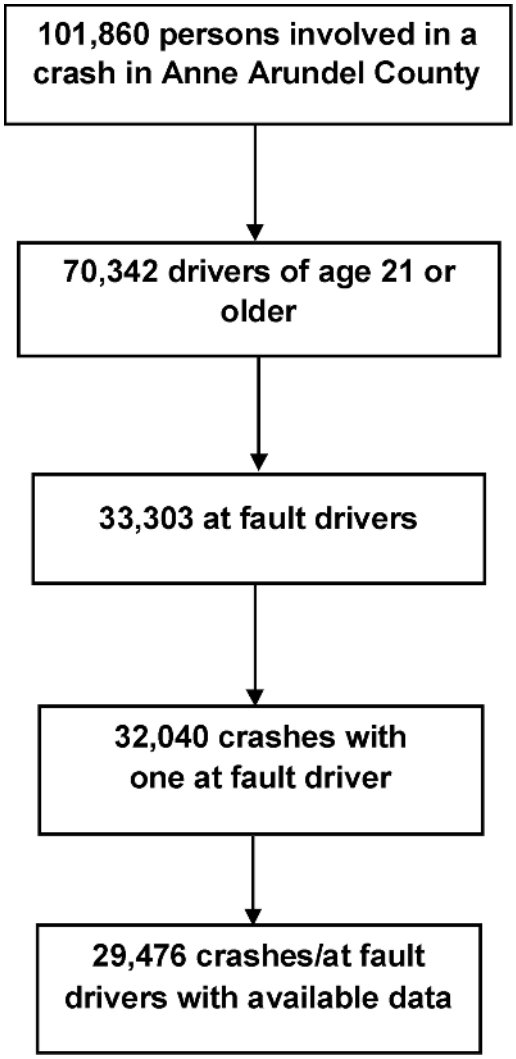

Fig. 2. Derivation of the study cohort.

where the casino is opened (Cotti and Walker, 2010). Rural and moderately sized counties were found to be more likely to see an increase in alcohol-related motor vehicle crash fatalities. They felt that casinos in less urban areas create a destination effect that attracts people from the surrounding areas. However, this effect may have an outsized impact on rural locations, which have few fatal crashes at baseline. Similarly, casinos in urban locations may also create this destination effect, but most drivers in urban areas are not intoxicated and do not have fatal crashes, so these crashes may not have been recorded in FARS. There is a dearth of evidence-based or peer-reviewed studies that address the questions and concerns of affected residents in the vicinity of casinos and resorts.

Understanding how crashes relate to casino development may help tailor future education, community planning, and enforcement campaigns to lessen negative community impact from the introduction of casinos to communities. This study used precise mapping technology (Geographic Information Systems [GIS]) to examine the effects that a new casino had on local traffic safety in a county in Maryland State. We hypothesized that the introduction of a casino would increase the proportion of nearby crashes (within one mile of the casino) when controlling for known risk factors (age, sex, race, intoxication, time of day, day of the week, and type of crash).

2. Methods

2.1. Description of the study site and surrounding area

The study takes place in Anne Arundel county, which is located along the Chesapeake Bay between Baltimore and Washington, DC. More than 500,000 people reside in Anne Arundel county, and the population has grown 7.1 % between 2010 and 2018 (Anon., 2018). The northern part of the county, where the casino of interest is located, is a mix of suburban and urban, especially around the I-97 corridor. The southern half of the county is considered semi-rural. The casino is located immediately adjacent to a large shopping center that opened in November of 2000. The shopping center contains more than 200 stores and more than 1.6 million square feet of space. The shopping center and casino are bordered on the north by I-295 and Route 100. Residential neighborhoods form the southern border of the shopping complex and casino. Baltimore-Washington International Airport is 2.5 miles north and east from the casino. The casino broke ground on January 27th, 2011 and opened on June 6, 2012 (Gorelick, 2012). About 10,000,000 people visit the casino annually (Capriel, 2016).

2.2. Study design

This is a retrospective cohort study of crashes occurring in Anne Arundel County, Maryland, between 2010 and 2014 (Kindelberger and Milani, 2015a). The unit of observation for this study was a motor vehicle crash, as recorded in digitized police reports. The final database included all crashes with police officer documentation indicating a driver of at least 21 years of age who was at fault for the crash. Drivers younger than age 21 were excluded from the analysis because the legal age for both gambling and drinking is 21 years in Maryland. Police officers assign characteristics to each crash (time of day, day of crash, location, single versus multi-vehicle crashes) and can cite contributing factors, such as weather conditions or driver intoxication (Milani et al., 2015). GIS mapping was applied to locate hotspots of traffic around the casino and locate crashes within and beyond the one mile driving distance and radius. The study was approved by the Institutional Review Board of the University of Maryland.

2.3. Outcome ascertainment

The outcome measure was defined as the ratio of the number of crashes occurring within one mile of the casino location, “as the crow flies” (i.e., close proximity) divided by the number of all other crashes in Anne Arundel County. A one-mile driving radius was chosen to encompass most roads that directly feed into the casino area; roadways just beyond the one-mile radius would include heavily traveled Interstate 95 and Maryland Route 32, which are likely to carry many vehicles that do not enter or exit roadways adjacent to the casino (Fig. 1). ArcGIS Pro [Version 2.1, Esri, Inc., Redlands, CA] (hereinafter ArcGIS) was utilized to spatially display all crashes.

Both spatial and non-spatial data were used in this research. All spatial data were projected in the World Geodetic System 1984 coordinates (NIMA (United States National Imagery and Mapping Agency), 2000) to ensure that the spatial relationships between data displayed on the map remained consistent by reducing measurement error.

The model development began with assessment of all crashes occurring in Anne Arundel County between January 2010 and December 2014 (Fig. 2). Crashes were plotted using a roadway inventory database from Maryland’s State Highway Administration (SHA) (Kindelberger and Milani, 2015b). A point layer was created in ArcGIS by placing a marker on the geodesic center of the casino building. Using the ArcGIS network analysis toolkit, a one-mile circular radius (“as the crow flies”) was used to distinguish the crashes close to the casino from the remaining Anne Arundel County crashes.

The 30-month period before the casino opened was defined as "pre-casino," (January 2010 to June 2012) and the 30-month period after the casino opened was defined as "post-casino." (July 2012 to December 2014). Therefore, the primary study analysis involved a comparison between the ratio of crashes occurring near the casino during the pre-casino period (Eq. (1)), and the ratio occurring within the same geographic radius during the 30 months of the post-casino period (Eq. (2)).

$$R_{Pre-casino} = \frac{N_{Crashes\ within\ one\ mile\ of\ the\ casino,\ before\ it\ was\ opened}}{N_{Crashes\ outside\ of\ one\ mile\ of\ the\ casino,\ before\ it\ was\ opened}} \quad (1)$$

$$R_{Post-casino} = \frac{N_{Crashes\ within\ one\ mile\ of\ the\ casino,\ after\ it\ was\ opened}}{N_{Crashes\ outside\ of\ one\ mile\ of\ the\ casino,\ after\ it\ was\ opened}} \quad (2)$$

2.4. Covariate ascertainment

Driver attributes included age, gender and substance use impairment. Preliminary partitioning of age into five-year intervals within a logistic regression model for the outcome of proximity revealed positive coefficients for intervals below age 40 and negative coefficients for intervals greater than or equal to age 40. Thus, age at the time of crash was dichotomized as 40 years or older versus younger than age 40. Crashes involving at-fault drivers who were considered impaired by police were compared with all other crashes. Drivers were considered to be impaired if they were reported to have been drinking, using drugs, or influenced by medication. Crash-related factors included the crash type, time and day of week. Crash type was categorized as single or multiple vehicle crash. Time of week distinguished weekday crashes (Monday to Friday) from weekend crashes (Saturday and Sunday). Time of the day was dichotomous: nighttime (9 p.m. to 6 a.m.) versus daytime (6 a.m. to 8 p.m.).

2.5. Data analysis

The relationships between potential covariates and both (a) the time period (before or after casino opening) and (b) the proximity of the crash to the casino (within one-mile versus outside one-mile radius) were assessed using the chi-square test. Results of the bivariate analyses determined which characteristics of the at-fault driver and crash factors may have influenced the change in the ratio of crashes occurring within the geographic radius. Multivariable logistic regression was used to assess the odds of crashing within the one-mile radius after the casino opened, relative to those odds before the casino opened, after adjusting for confounders and other important independent covariates. Each covariate was also considered as a potential effect modifier. Odds ratios (OR) and their 95 % confidence intervals (CI) were obtained. For all analyses, a p-value less than 0.05 (corresponding to a 95 % CI of the OR that does not include 1.00) was considered statistically significant. SAS [Version 9.4, SAS Institute, Inc., Cary NC] was used to conduct statistical testing.

3. Results

A total of 101,860 persons were involved in 43,328 motor vehicle crashes in Anne Arundel County during the five-year study period; approximately 69.1 % (n = 70,342) were drivers of age 21 or older (Fig. 2). After excluding multiple vehicle crashes where more than one driver was at fault, crashes where the driver was not at fault, and cases with missing data, our final sample size was 29,476 crashes. Approximately 1.9 % (n = 550) of the crashes occurred within the one-mile radius surrounding the casino during the study period.

The number of crashes increased 18.4 % between the pre-casino (n = 13,495) and post-casino (n = 15,981) periods. There was an association between the occurrence of motor vehicle crashes before and after the opening of the casino, with proximity to the facility (Eqs. (3) and (4), Table 1). In Eq. (3), the unadjusted model, i refers to the probability of a crash, β refers to the regression coefficients, X refers to the indicator variable for whether the crash occurred before or after the casino opened. In Eq. (4), the adjusted model includes all of the crash characteristics. Crashes within the one-mile radius were 23 % more likely to occur in the post-casino period relative to the pre-casino period (OR = 1.23, 95 % CI: 1.04–1.46).

Table 1
Odds ratios and 95 % confidence Intervals for the effect of post-casino vs. pre-casino on the outcome of crash frequency within one mile of the casino.

	Number of Crashes	Model 1[a] OR (95 % C.I)	Model 2[b] OR (95 % C.I)
Post period	15,981	1.23 (1.04 – 1.46)	1.23 (1.04 – 1.46)
Pre period	13,495	1.00 (reference)	1.00 (reference)
p-value		0.02	0.02

[a] Unadjusted model.
[b] Adjusted for Weekend vs. Weekday and Impaired vs. Not impaired.

$$\log\left(\frac{p_i}{(1-p_i)}\right) = \beta_0 + \beta_a X_a \quad (3)$$

$$\log\left(\frac{p_i}{(1-p_i)}\right) = \beta_0 + \beta_{Period}X_{Period} + \beta_{Age}X_{Age} + \beta_{Gender}X_{Gender} + \beta_{Impairment}X_{Impairment} + \beta_{Day}X_{Day} + \beta_{Time}X_{Time} + \beta_{Single}X_{Single} \quad (4)$$

Analysis of potential driver and crash related confounders of time period (Table 2) indicated that, in all of Anne Arundel County, weekend crashes were slightly less likely to occur in the post-casino period than the pre-casino period (24.7 % vs. 26.0 %, p = 0.01). Impaired crashes were also less likely to occur post-casino when compared to pre-casino (10.7 % vs. 11.9 %, p = 0.002). There were no other significant covariates among the possible confounders for time period.

Bivariate analyses testing the relationship between driver and crash attributes with crash proximity yielded significantly higher proportions of weekend crashes and crashes involving younger drivers within the one-mile radius. In addition, impaired crashes were significantly less likely to occur close to the casino as opposed to beyond the one-mile radius. Gender, time of day, and crash type were not significantly associated with proximity. Upon adjustment for the confounder variables (weekend vs. weekday and impaired vs. not impaired), the effect of time period on outcome remained virtually the same, with more crashes occurring close to the casino after it opened (OR = 1.23, 95 % CI: 1.04–1.46, Table 1).

Additional analysis of the association between time period and crash proximity to the casino involved fitting a multivariable logistic regression model to adjust for additional driver and crash factors that are known to influence crash frequency.

Effect modification was assessed by adding cross product terms with time period and each individual covariate to the model (Table 3). The association between crash proximity and time period differed by crash type. Interactions between time period and the remaining covariates (nighttime versus daytime, weekend versus weekday, driver age, gender, impairment) were not statistically significant. Examination of the occurrence of the independent covariates within the 1-mile radius, as opposed to outside the radius, revealed the following:

a Crashes on weekends were more likely to occur within the one-mile radius when compared to weekday crashes (OR 1.39, 95 % CI: 1.15–1.67).
b The likelihood of the crash within a one-mile radius was significantly higher for drivers younger than age 40 relative to older drivers (OR 1.74, 95 % CI: 1.45–2.08).

Table 2
At fault driver and crash characteristics by period and proximity to casino.

	Period			Radius		
	Pre	Post	p value	One Mile	Outside One Mile	p value
Covariates	45.8 % (13,495)	54.2 % (15,981)		1.9 % (550)	98.1 % (28,926)	
Age (in years)						
Older (50 – 98)	46.8 % (6310)	45.9 % (7337)	0.15	33.4% (184)	46.5 % (13,463)	< 0.001
Younger (21 – 49)	53.2 % (7185)	54.1 % (8644)		66.6 % (366)	53.5 % (15,463)	
Sex						
Male	61.2 % (8256)	61.1 % (9766)	0.90	57.4 % (316)	61.2 % (17,706)	0.07
Female	38.8 % (5239)	38.9 % (6215)		42.6 % (234)	38.8 % (11,220)	
Impairment						
Yes	11.9 % (1601)	10.7 % (1709)	0.002	8.0% (44)	11.3 % (3266)	0.02
No	88.1 % (11,894)	89.3 % (14,272)		92.0 % (506)	88.7 % (25,660)	
Day of the week						
Weekday (M–F)	74.0 % (9990)	75.3 % (12,030)	0.01	68.7% (378)	74.8 % (21,642)	0.001
Weekend (Sa–Su)	26.0 % (3505)	24.7 % (3951)		31.3 % (172)	25.2 % (7284)	
Time of the day						
Night (9p.m.–5a.m.)	22.3 % (3010)	21.9 % (3502)	0.42	23.4% (129)	22.1 % (6383)	0.44
Day (6a.m.–8a.m.)	77.7 % (10,485)	78.1 % (12,479)		76.6 % (421)	77.9 % (22,543)	
Crash type						
Single vehicle	27.0 % (3647)	26.9 % (4295)	0.77	23.8% (131)	27.0 % (7811)	0.10
Multiple vehicle	73.0 % (9848)	73.1 % (11,686)		76.2 % (419)	73.0 % (21,115)	

Table 3
Odds ratio and 95 % confidence intervals for main effects and interaction terms on outcome of crash frequency within one mile of the casino.

Effect	OR	95 % CI
Single vehicle		
Post period (vs. Pre period)	0.86	0.61 – 1.22
Multiple vehicle		
Post period (vs. Pre period)	1.38	1.13 – 1.68
Age < 40 (vs. Age 40 +)	1.74	1.45 – 2.08
Male (vs. Female)	0.86	0.72 – 1.02
Impaired (vs. Unimpaired)	0.61	0.44 – 0.84
Weekend (vs. Weekday)	1.39	1.15 – 1.67
Nighttime (vs. Daytime)	1.13	0.91 – 1.41

c Impaired drivers were significantly less likely than unimpaired drivers to be involved in crashes within one mile of the casino.
d Neither gender (OR 0.86, 95 % CI: 0.72–1.02) nor time of day (OR = 1.13, 95 % CI: 0.91–1.41) were significant risk factors for crash frequency within a one-mile radius.

An unadjusted stratified examination of the period by crash type interaction term indicated there was no association between period and proximity among single vehicle crashes; this result remained the same following adjustment by both (a) the confounder variables and (b) other driver and crash characteristics (OR = 0.86, 95 % CI: 0.61–1.22). Among multiple vehicle crashes, however, crashes during the post-casino period were almost 40 % more likely than crashes during the pre-casino period to occur within the one-mile radius (OR = 1.39, 95 % CI:1.14–1.69]). This association between period and proximity also did not change following adjustment by the confounding variables and the remaining covariates.

4. Discussion

In this retrospective study of crashes occurring within Anne Arundel County, Maryland, there was an association between the number of at-fault crashes within one mile of a casino and the period after the casino was opened. That association depended on the number of vehicles involved in the crash. Other crash characteristics, such as driver age, driver impairment, and time of week, were each shown to be independently related to crash proximity to the casino.

The greater risk of crashes involving multiple vehicles after the casino was opened could be attributed to the sudden increase in traffic due to the presence of the casino or the level of traffic infrastructure present at the time (Quddus et al., 2009). It is standard practice in Anne Arundel County and Maryland State generally for traffic impact studies to be completed prior to the furnishing of a building permit (Anon, 2020). The casino is located next to the largest mall in Maryland (Anon., 1998). Construction of the mall included the creation of several roadways that were added to access its parking lots. The significant association for multiple vehicle crashes may suggest that the additional traffic volume to the area exceeds the capacity of some of the traffic control infrastructure (Golob and Recker, 2004). This presents an opportunity to revisit the traffic management infrastructure within the study area to determine whether it is enough for the increased demand brought to the area by the casino.

Analysis of independent factors indicated that weekend crashes were more likely than weekday crashes to occur within close proximity of the casino. Statewide crash trends from the past 20 years indicate that weekend numbers increase for certain crash types, such as those involving motorcycles, and for all vehicle types in locations such as Maryland's beaches (Maryland Highway Safety Office, 2020). It is believed that areas with recreational opportunities see increases in the number of crashes during the weekend, as more people have an opportunity for recreational activities when they are not working (Pigman et al., 1978). This increase follows the trend for vehicle miles traveled (VMT) in other recreational destinations across Maryland. Future analysis would be helpful to determine if the seasonal effect of crashes and traffic volume tracks with the findings at the casino, and if these findings in proximity to the casino are distinguishable from other recreational locations.

The likelihood of crashes among younger drivers may be related to the demographics of specific gambling populations. Maryland's casinos only had slot machines before law permitted table games in 2012 (Maryland Lottrey, 2012). However, shortly after the opening of the casino in June 2012, table games were permitted (Freedom du Lac,

2013). The population of patrons who use table games skew younger than those who use slot machines (Millar, 2008; Petry, 2002; McCarthy et al., 2013; Anowar et al., 2013), so this effect is particularly likely to happen in later years following the casino opening. Most importantly, in Anne Arundel County and statewide, the youngest age group (16–24 years old) has the highest proportion of at-fault drivers compared to any other age group. Combined with marketing efforts by the casino to attract younger patrons due to the table games, this could very well explain the role of age in at-fault drivers within the radius (Millar, 2008; Petry, 2002; McCarthy et al., 2013). It is also possible that the oldest drivers who gamble are more likely to travel with a companion who does the driving for them.

Unimpaired drivers were found to be significantly more likely than impaired drivers to be involved in crashes within close proximity to the casino center. This conflicts with other authors who found that casinos and increased availability of alcohol are associated with an increased rate of alcohol-related crashes (Cotti and Walker, 2010; Wong and Christine, 2020; Dezman et al., 2016; Lavoie et al., 2017; Kufera et al., 2006). The casino in this study is close to a large shopping center, which may preferentially attract drivers who do not plan to drink. This also increases the traffic flow in the immediate area, thereby increasing exposure for the occurrence of minor traffic crashes. Additionally, the casino is readily accessible by multiple forms of public transportation that might result in a reduction of impaired drivers crashes (Jackson and Owens, 2011; Morrison et al., 2018).

Further research will be needed to ascertain the risk factors responsible for the increase in motor vehicle crashes. Although there was a significant increase in the number of multi-vehicle crashes within the 1-mile radius since mid-2012, the total number of crashes both within Anne Arundel County (where the casino is located) and statewide have increased every year from 2012 to 2016. Thus, it is possible that factors related to the wider crash trends may have influenced the results observed in the study area.

5. Limitations

Although our model indicated a change in impaired crashes over time within the 1-mile radius, there were some limitations to the crash report data. Data on the daily number of patrons frequenting the casino would be important in determining if those involved in motor vehicle crashes were from the casino or other establishments around the area. A more discrete definition of impairment is also necessary to clearly identify the cause of the increase in motor vehicle crashes indicated around the casino after it was opened. It is important to note that a driver's impairment is not completely detectable by law enforcement (McGuire, 1986; Stuster, 2006), nor do all impaired drivers become involved in a police-reported crash (Castle et al., 2014). Therefore, the impaired drivers captured in the crash data represent a subset of the total impaired-driving population in our study area. For instance, there may have been impaired drivers who were stopped and given citations without crashing, as well as impaired drivers in the area who were never involved in a police-reported crash. These drivers would not have been included in the database used for this analysis.

Most importantly, crash data do not fully explain driver behavior (Boufous et al., 2010; Grant et al., 1998). For instance, crash data will not show where each driver was going to/coming from prior to the crash. As such, we can only use geographic radii to determine where the casino's impact on traffic is most likely located. However, only a fraction of total drivers in our study area were involved in a crash, and not all crashes were reported by police. If a crash was reported by police, it is still possible that the key variables for our analysis may have been marked unknown or otherwise excluded from the report.

6. Conclusions

Importantly, casinos open a new venue for highway safety efforts, potentially allowing highway safety professionals to target some of drivers most at-risk for being involved in a crash. Little information on the effect of casinos on traffic crashes is available nationally, especially in Maryland. However, this research has found that the introduction of a casino may influence the type of crashes that occur, particularly those within close proximity to the location. Casinos are a relatively new industry in Maryland and each of the six casinos in the state have different characteristics. For example, the casino that is the subject of this analysis is located next to a mall in a heavily developed neighborhood, while the casino in Perryville, Maryland is a stand-alone site located in a rural setting. The traffic patterns, and associated safety implications, may be different. Further evaluations of the effect of each Maryland casino on local highway safety may help to determine which highway safety education campaigns would be most effective in particular areas.

Author contribution statement

All authors have reviewed and approved the final draft of the manuscript.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.aap.2020.105554.

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