Cannabis Legalization, Crash Incidence, and Injury Severity in Illinois: Evidence from Seven Years of Linked Crash and Hospital Data

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Introduction

The use of recreational cannabis was legalized in Illinois effective January 1, 2020, following the enactment of similar legislation passed earlier in states like Oregon, Washington, and Colorado. As in those states, policymakers in Illinois are interested in understanding any potential public health side effects of legalization, including effects on road safety. This study utilizes seven years of linked hospital and crash data from 2016 through 2022, three years of which represent crashes occurring post legalization, to investigate the associated effects, if any, legalization had on crashes and road safety. This sample of analyzed linked crashes likely presents an undercount of the true scale of cannabis-positive motor vehicle crashes due to the nature of linked data. Still, the share of incidents and associated characteristics of crashes and those involved likely accurately represent the true population. However, cannabis screening is not uniformly administered nor is it necessarily a required test to be conducted by hospital care providers, which likely leads to unobserved positive cases.

For this analysis, we consider only those cases that were diagnosed as cannabis-positive at the hospital as identified in the linked data using the International Classification of Diseases, Tenth Revision coding (ICD10). Crash data alone are silent on the presence of cannabis in the body, so a successful linkage with hospital data is necessary to study cannabis prevalence. A positive cannabis test does not necessarily imply intoxication, nor does a positive test necessarily imply responsibility, or fault, for the crash. In service to the avoidance of speciousness, the term cannabis-positive is employed here to communicate its presence while maintaining an absence of fault. This research presents an early analysis of trends within the geographical boundaries of Illinois of panel data of cannabis related crashes; policymakers and researchers should exercise caution when extrapolating observed trends in these data into future policies and conclusions.

Resulting from our analysis we find, in part, a statistically significant but weak effect between cannabis legalization and an increased rate of cannabis-positive linked crashes when aggregated annually and weighted per 1 billion vehicle miles traveled at the county level. Additionally, the post-legalization period tended to have slightly elevated rates of all road users involved in cannabis-positive linked crashes – especially the year 2020, before a modest return in the succeeding years to a somewhat elevated mean. Hospital charges for all injured crash patients increased in 2020 and remained elevated for cannabis-negative road users. The persistently elevated mean charge of a cannabis-positive road user pre-legalization was reduced a bit in the succeeding years from its 2020 high. Beginning in 2020, mean injury severity among cannabis-positive, and negative, linked crash patients intuitively increased in kind along with elevated hospital charges, as measured by the injury severity score. In a similar way to the other metrics, mean injury severity among both cohorts realized a sort of reversion to the pre-legalization mean in the years succeeding 2020. Though the mean injury severity of the linked cannabis-positive cohort of crash patients was previously, and remains, nearly three times that of cannabis-negative road users.

Measuring the prevalence of poverty in addition to insufficient access to reliable transportation (car ownership) can be useful metrics of the incidence of relative societal disadvantage. The mean poverty rate, measured at the zip code level, of those involved in cannabis-positive crashes increased to a seven year high in 2020 before declining slightly in 2021 and 2022 to a still somewhat elevated level relative to pre-legalization. Still, the downward trend is forecasted to return to pre-legalization levels by 2024. The mean carless household rate (households without car access, measured at the zip code level) of those involved in cannabis-positive crashes increased by about three percentage points in 2020 relative to the pre-legalization period. This trend, too, is downward in the years succeeding 2020 though at a slower rate relative to poverty.

The share of Black road users involved in linked cannabis-positive crashes increased in 2020 by 2.8 percentage points greater than the upper boundary of our forecasted 95% confidence interval (based on data from 2016 through 2019). The Black share remained elevated above the upper boundary in 2021 and 2022. The share of White road users involved in linked cannabis-positive crashes decreased in 2020 by 0.6 percentage points lower than the lower boundary of our forecasted 95% confidence interval. The White share remained lower than forecasted in 2021 before increasing to just within the lower boundary in 2022 by 0.4 percentage points.

An important factor for consideration here is the confounding influence introduced to the post-legalization period by the onset of the COVID-19 global pandemic. As demonstrated by this research team (Edwards, 2022), COVID catalyzed risky roadway behaviors that led to increased rates of severe injury, death, and involvement of Black and disadvantaged road users. Many others have documented increased rates of injury and death associated with aggressive driving behavior catalyzed by COVID, especially speeding, in states where cannabis was not recently legalized (Doucette et al., 2020; Huang et al., 2020; Lee et al., 2020; Liao et al., 2020; Lin et al., 2021; Stiles et al., 2021).

Following a review of related literature which finds many various methods, data sources, and conclusions in the research, summary statistics of various crash factors are presented in the Results section. A binary logistic regression model is described, performed, and interpreted toward the end of the Results section. Finally, the discussion section reviews key takeaways, potential policy implications, and future research.

Related Research

Against the backdrop of an ongoing national reckoning with impaired driving, the years long, gradual, and stratified nature of cannabis liberalization legislation has inspired a steady stream of academic research into the effect on public safety. Yet when it comes to understanding how cannabis legalization affects road safety, the research paints a complex picture often with contradictory findings.

Beginning broadly with vehicle crashes in general, some studies have found an increase in the number of people who drive under the influence of cannabis post legalization (Roffman 2016; Salomonsen-Sautel et al. 2014; Delling et al. 2019; Jones 2019; Borst et al. 2020; Lensch 2020; Windle et al. 2021). However, not all research agrees on this. Some studies show mixed results (Masten and Guenzburger 2014; Santaella-Tenorio et. al 2017; Sevigny 2018), while others show no significant change (Romano et. al 2014), and yet others suggest a decrease in impaired driving post cannabis legalization (Anderson et al. 2013; Rotermann 2020).

Cannabis legalization for recreational use is but one approach to liberalization; another approach taken by policymakers has been decriminalization. Some research finds that decriminalization can lead to an increase in both vehicle crashes and risky driving behaviors (Woo et. al 2019; Lee et. al 2018; Hamzeie et. al 2017; Pollini et. al. 2015; Couper and Peterson 2014), still others have found null results (Kruse et. al 2021; Keric et. al 2018).

Research regarding the relationship between fatal crashes and cannabis is among the more common type of study, likely because those data are readily available; yet findings are nonetheless contradictory. Some research suggests an increase in fatalities involving cannabis post legalization (Salomonsen-Sautel et al. 2014; Steinemann et al. 2018; Aydelotte et al. 2019; Kamer et al. 2020; Nazif-Muñoz et al. 2020; Tefft and Arnold 2021; Windle et al. 2021), while others disagree. Some of those in disagreement find that the increase in fatal crashes is just not that big, or even approaching zero in some cases (Aydelotte et al. 2017; Hansen et al. 2020; Callaghan et al. 2021), and the results vary depending on the location under analysis (Lane and Hall 2019; Santaella-Tenorio et al. 2017; Santaella et al. 2020).

One explanation for variation in findings of the effect of cannabis legalization on fatal crashes is the scope of liberalization. As in whether it was narrowly permitted for medical use, or more widely permitted for recreational use. Some research has disagreed about whether medical (Benedetti et. al 2021) or recreational legalization (Lee et. al 2018) has a greater effect on fatal crashes. Another explanation for variation in crash outcomes is the use of safety equipment. Research suggests that crashes involving cannabis-impaired driving are more likely to involve people not using protective equipment like helmets and seatbelts (Steinemann et al. 2018; Borst et al. 2020). Still, not all research agrees: some studies show an increase in the use of protective equipment among drivers impaired by cannabis (Lensch et al. 2020).

Another important factor for consideration is how cannabis use may be related to other risky behaviors. Some research suggests that people who use cannabis are more likely to drive under the influence of alcohol and engage in risky driving behaviors (Alonso et al. 2014; Romano et al. 2014: Alonso et al. 2015; Tefft and Arnold 2021). However, there's also evidence that cannabis legalization might lead to less impaired driving involving alcohol – possibly because some might choose cannabis over alcohol (Anderson et al. 2013). Furthermore, some studies indicate that drivers in states where cannabis is legal might actually drive more safely, possibly because there is more awareness about the dangers of driving under the influence due to education campaigns by state governments (Lensch et al. 2020; Rotermann 2020). However, other research suggests that legalization decreases the perceived dangers involved in cannabis consumption (Palamar et. al 2014). These contradictory findings suggest more work is needed to better understand the relationship between cannabis legalization and risky driving behavior.

A key component of understanding the effect of cannabis legalization on traffic safety is understanding the segments of population who are most likely to engage in impaired driving. Young drivers, defined as those under the age of 30, who are already more susceptible to crash involvement, tend to be at higher risk for driving cannabis-impaired (Fergusson and Horwood 2001; Siliquini et al. 2010; Siliquini et al. 2011; Couper and Peterson 2014; Hamzeie et. al 2017; Steinemann et. al 2018; Woo et. al 2019; Rotermann 2020; Borst et al. 2021). Sex also plays an important role, as males are more likely than females to drive cannabis-impaired (Couper and Peterson 2014; Hamzeie et. al 2017; Woo et. al 2019; Rotermann 2020). Some research finds that drivers who consume alcohol are also more likely to also have consumed cannabis (Hamzeie et. al 2017; Delling et. al 2019; Jones et. al 2019; Woo et. al 2019; Nazif-Munoz et. al 2020). Finally, geographic proximity to cannabis dispensaries increases the likelihood of a cannabis related motor vehicle crash (Sevigny 2018; Aydelotte et. al 2019).

A confounding factor in the literature is that studies use varying data sources, and these varying sources often lead researchers in different directions. Among methods observed, we reviewed self-reported surveys (Lensch et. al 2020; Rotermann 2020; Benedetti et. al 2021), urine or blood analysis (Couper and Peterson 2014; Delling et. al 2019; Wood et. al. 2019; Borst et. al 2020; Kruse et. al 2021; Tefft and Arnold 2021), FARS (Pollini 2015; Aydelotte et. al 2017; Hamzeie 2017; Lee et. al 2018; Aydelotte et. al 2019; Woo et. al 2019; Hansen et. al 2020; Santaella et. al 2020; Tefft and Arnold 2021; Windle 2021), surveys of medical professional assessments (Keric et. al 2018), data collected by the CDC (Lane and Hall 2019), and data collected through the national EMS reporting system (Callaghan et. al. 2021). Other studies utilize self-reported surveys of behavior as their measure (Lensch et. al 2020; Rotermann 2020). Considering these disparate data sources, it is perhaps not a surprise that existing research points in numerous directions.

Another confounding factor is the focus by much of this research on fatalities – with some notable exceptions that go beyond (Delling et. al. 2019; Borst et. al 2020; Callaghan et. al. 2021). Using data that goes deeper to include other less severe injuries, such as the Motor Vehicle Data Linkage data used here, permits a deeper understanding of the relationship between cannabis legalization and traffic safety.

Additionally, researchers cannot randomly assign legalization status to states. This makes it difficult to discern whether findings from one state can be applied either universally, or individually, to another locality. However, previous research has concluded that of all U.S. states, Illinois most closely resembles the rest of the country – particularly when it comes to race, education, age, income, and religiosity (Khalid 2016). Suggesting, perhaps, findings utilizing Illinois data on this issue may be more useful to a wider range of policymakers relative to other states' findings.

Research purpose and hypothesis

With the published research seemingly unable to reach a consensus on the relationship between the liberalization of cannabis legislation and motor vehicle crashes, this study aims to provide a bit more clarity from an Illinois perspective. Though legalization was codified effective 1/1/2020, decriminalization in Illinois began as far back as 2012 and incrementally became more liberal over time (Annual Cannabis Report, 2023). This incremental liberalization may have had a beneficial dampening effect as the populace gradually adapted. Counterfactually and consequently, any measurable and sustained shock to the system incurred at a step in the legalization journey may have occurred prior to our first study year of 2016 – and therefore remains unobserved. Finally, our *research question* is simply: did cannabis legalization have an effect on the incidence of motor vehicle crashes and injuries in Illinois? As follows, our *null hypothesis* for this research is that cannabis legalization had no effect on motor vehicle crash incidence or injury.

Sources and Methods

Research Design

This retrospective analysis of panel data from across the state of Illinois utilizes seven years of linked crash and hospital discharge data spanning 2016 through 2022. As pioneered elsewhere (Aydelotte et al., 2019; Doucette et al., 2021), crash events occurring after a population-wide public health intervention (cannabis legalization in Illinois in this case) have received treatment group designation. While in recognition of the natural experiment that transpired, crash events preceding the intervention received a placebo group designation. As is common with natural experiments, the linked data are treated here with an interrupted times series method of analysis (Bernal et al., 2016; Craig et al., 2017).

Crash and hospital data linkage

Funded by a grant from the Illinois Department of Public Health in collaboration with the Illinois Department of Transportation and the University of Illinois at Springfield, Illinois crash and hospital records for the years 2016 through 2022 were successfully linked. The linkage was accomplished using the software LinkSolv – consisting of probabilistic linkage methods developed in the National Highway Traffic Safety Administration's Crash Outcome Data Evaluation System program (McGlincy, 2021). A combination of data fields common to both files were identified as those with the highest success rate of linking the crash and hospital files: county, victim age, crash date, victim date of birth, and victim sex. Geographical tolerances were permitted for nearby counties since the crash may have occurred in a county different from that of the hospital where treatment was received. Crash date tolerances were also permitted one day into the future to allow for the dawning of a new day before a crash victim reaches a hospital. Cook County, home to Chicago, is where some 40% of the Illinois population resides, effectively making county a relatively indiscriminate match field – which is a factor controlled for in the LinkSolv software. These linked files are critical in our understanding of the effects of motor vehicles on the lives of the citizens of Illinois. Such an investigation as presented here would not be possible without the successful linkage of the disparate crash and hospital files.

The hospital files include rich (yet not personally identifiable) individual patient data who were admitted under urgent, emergency, and trauma admission types. Individual patient race, ethnicity, sex, and age are included as fields in the hospital files, among many others. A diagnosis of the presence of intoxicating substances conducted at the hospital is also included as a data field and investigated as it may relate to contributing crash factors. Though toxicology results are present for several substances this research focuses on the presence of cannabis.

Results

The results section begins with summary statistics and analyses of various components of cannabis-related crashes. Following these statistical analyses we present and interpret a binary logistic regression model that estimates crash factors related to cannabis legalization. Unless otherwise stated, all analyses use the linked crash-hospital data set.

Hospital charges

A few very high outliers artificially inflate annual mean hospital charges, so means are accompanied by the presentation of median and standard deviation to enable a fuller conceptualization of the distribution (**Figures 1** and **2**). **Figure 2** shows a steady and fairly flat trend across the study period in median hospital charges among all road users being treated for injuries sustained in a cannabis-positive crash. Mean hospital charges show a slight yet consistent increase across the study period before falling a bit in 2022 to approximately 2018 levels. As is made clear in **Figures 1** and **2**, distribution of charges is wide, peaking in 2019 before falling in 2022 to approximately 2017 levels of standard deviation.

Figure 1: Distribution of hospital charges for treatment of injuries sustained by all road users involved in a cannabis positive crash in Illinois from 2016-2022

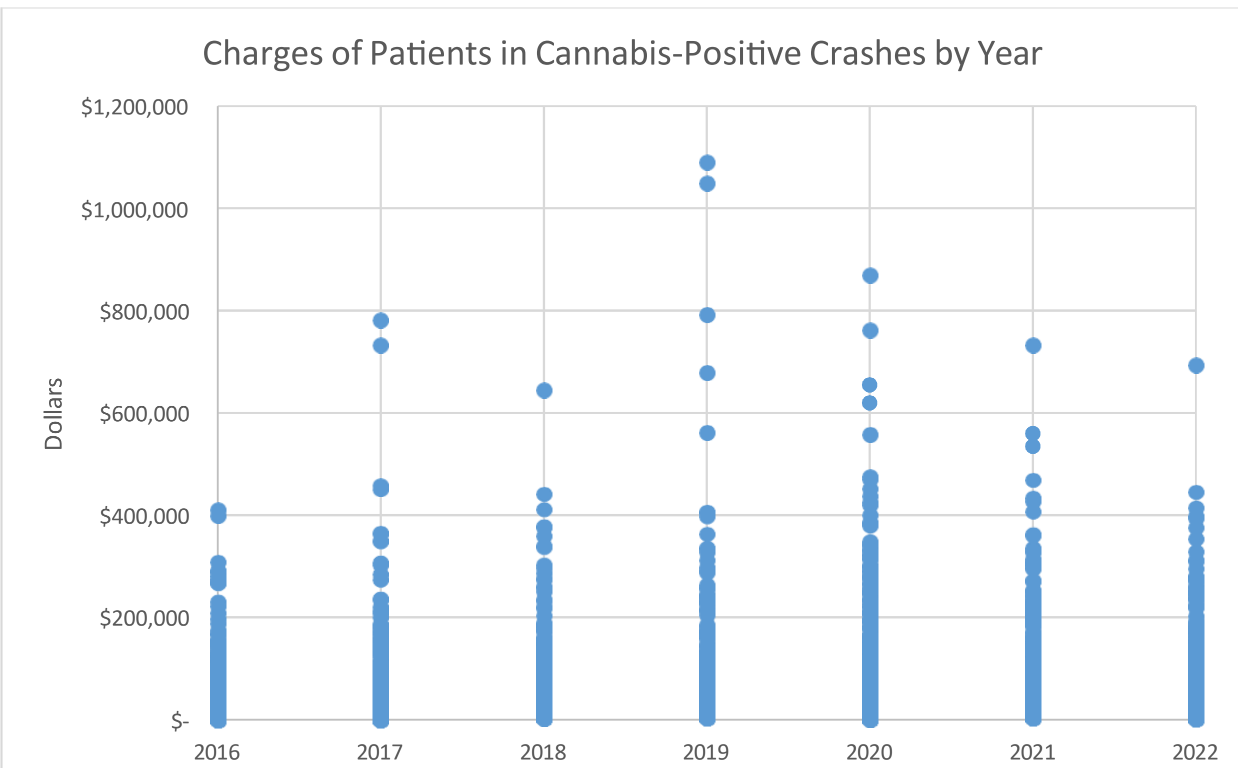
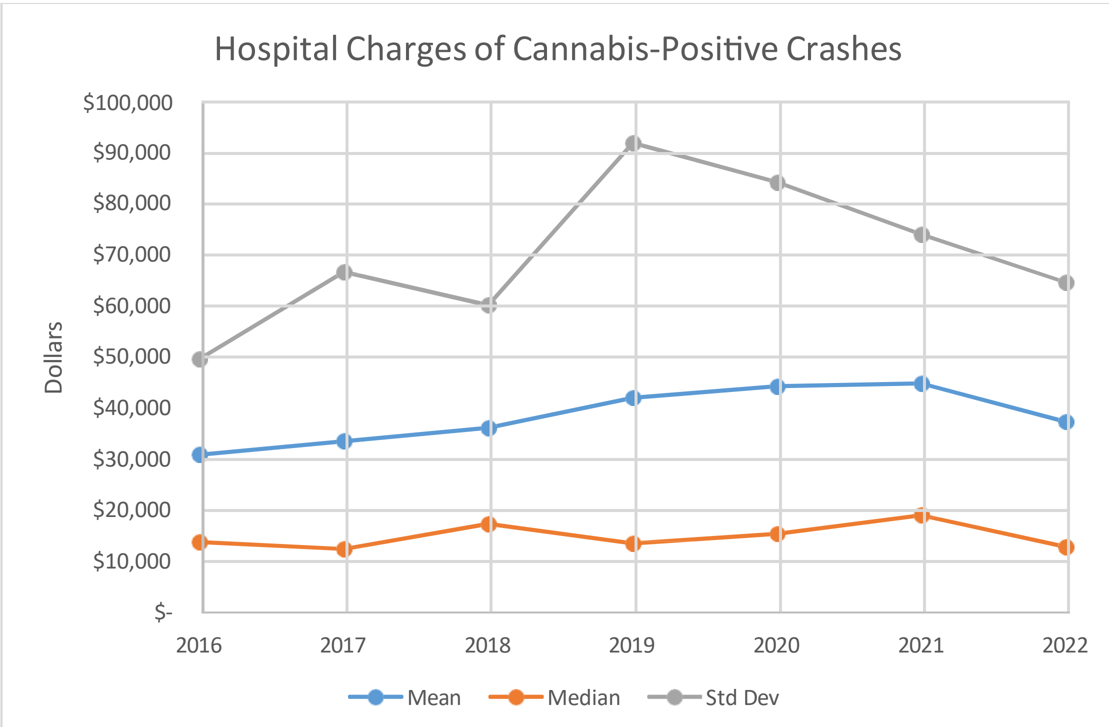
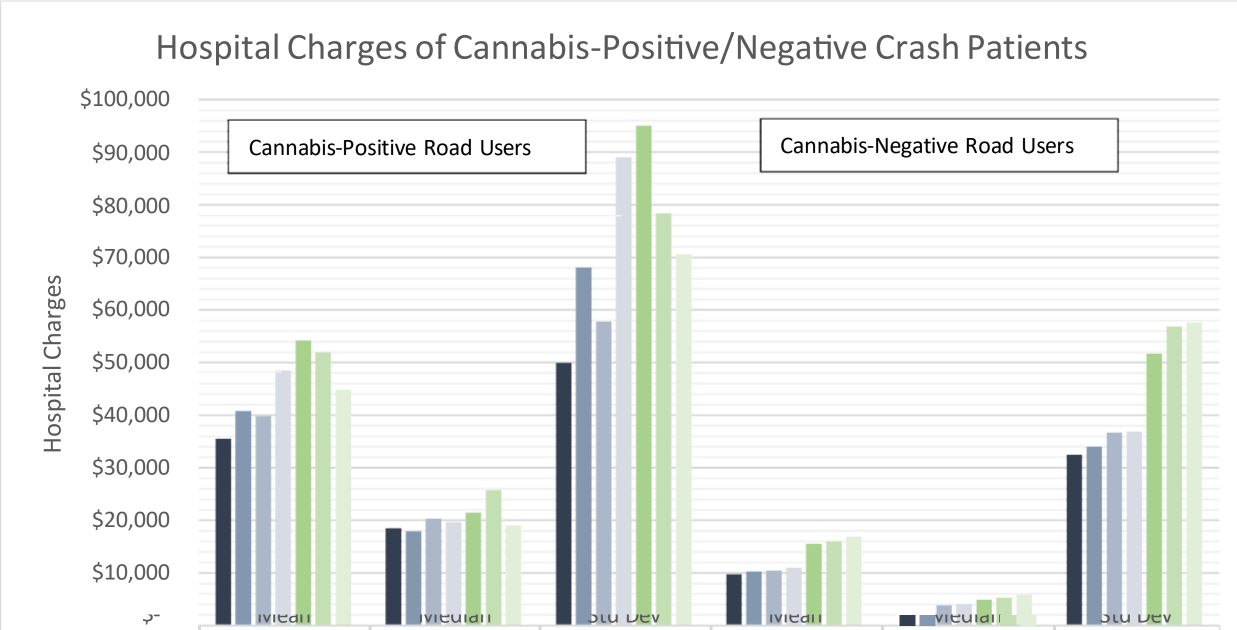


Figure 2: Mean, median, and standard deviation of hospital charges for patients being treated for injuries sustained in a cannabis-positive crash



When comparing charges of cannabis-positive crash patients to cannabis-negative crash patients, a clear divide emerges. **Figure 3** shows both cohorts saw modest increases in the cost of hospital care in 2020, before slightly decreasing for cannabis-positive road users, yet remaining elevated for cannabis-negative road users. As a result, the mean charge of a cannabis-positive crash patient was 3.5 times greater than the mean charge of a cannabis-negative crash patient; and the median charge of a cannabis-positive patient was 4.5 times greater than the median charge of a cannabis-negative crash patient. These disparities in charges between the two cohorts existed prior to cannabis legalization and persisted afterward. Nearly 35% (1,926) of cannabis-involved crash patients' primary payer was either Medicare or Medicaid. Nearly 37% (1,357) of cannabis-positive road users' primary payer was either Medicare or Medicaid.

*Figure 3: Summary statistics of hospital charges by cannabis-positive/negative road users involved in a motor vehicle crash from 2016-2022 in Illinois**



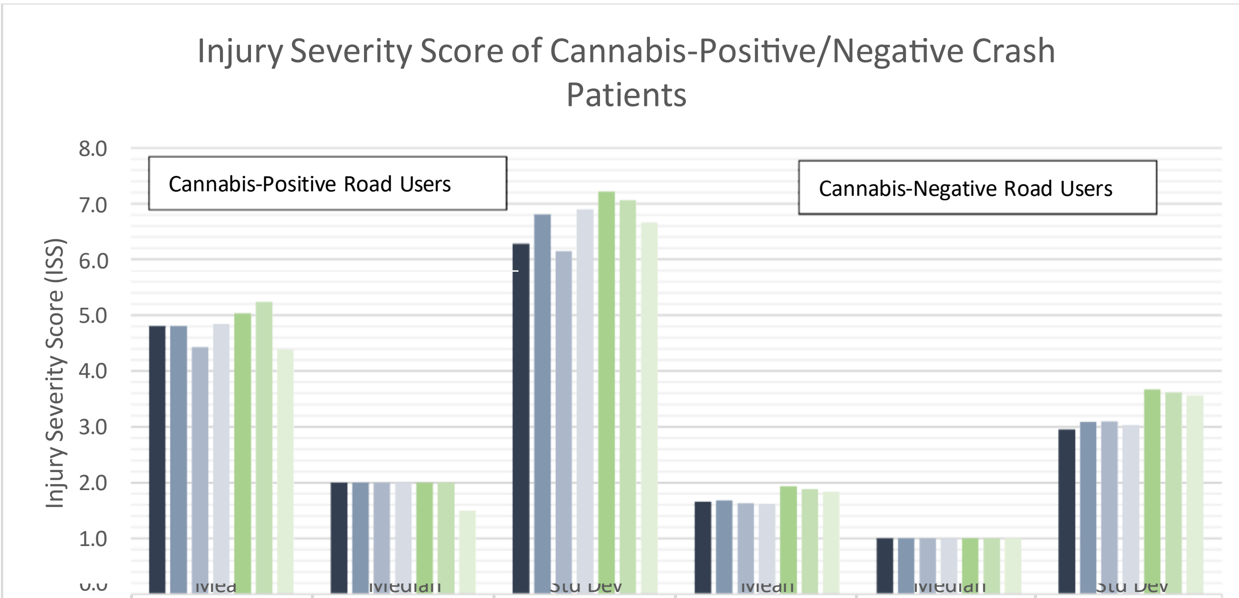
	Mean (Cannabis-Positive)	Median (Cannabis-Positive)	Std Dev (Cannabis-Positive)	Mean (Cannabis-Negative)	Median (Cannabis-Negative)	Std Dev (Cannabis-Negative)
2016	$35,500	$18,488	$49,883	$9,766	$3,421	$32,461
2017	$40,787	$17,901	$68,031	$10,264	$3,737	$33,968
2018	$39,804	$20,310	$57,764	$10,480	$3,856	$36,718
2019	$48,514	$19,649	$89,013	$11,016	$4,014	$36,860
2020	$54,243	$21,484	$95,002	$15,550	$4,957	$51,666
2021	$51,935	$25,741	$78,386	$15,922	$5,300	$56,870
2022	$44,790	$19,045	$70,621	$16,941	$5,821	$57,607

**Gray shaded years indicates pre-legalization, green shaded years indicates post-legalization*

Injury severity among cannabis-negative/positive road users

Elevated hospital charges logically correlate with more severe injury among those involved in motor vehicle crashes. As seen just above, cannabis-positive road users typically have much higher hospital charges related to their medical care, compared to cannabis-negative patients. The injury severity score (ISS) provides an overall assessment for patients with multiple injuries, where the most severe injury in each of six body regions is used to calculate a value between 0 and 75; a score of 75 is unsurvivable (Javali et al., 2019). **Figure 4** shows that the distribution of ISS by cannabis status is similar to the distribution hospital charges. The mean ISS of cannabis-positive road users involved in motor vehicle crashes was consistently about 2.7 times greater than cannabis-negative patients. Due to the manner in which ISS is calculated and our large sample sizes, there is little variation in median ISS – though median ISS among cannabis-positive patients was consistently twice that of cannabis-negative patients. Still, mean ISS among cannabis-positive road users fell in 2022 to their lowest levels of the study period. In a similar way to hospital charges, disparities between cannabis status cohorts existed before legalization – a trend which continued post legalization.

*Figure 4: Summary statistics of injury severity score (ISS) by cannabis-positive/negative road users involved in a motor vehicle crash from 2016-2022 in Illinois**



	Mean	Median	Std Dev	Mean	Median	Std Dev
2016	4.805	2	6.284	1.659	1	2.956
2017	4.803	2	6.806	1.685	1	3.088
2018	4.424	2	6.147	1.632	1	3.096
2019	4.837	2	6.897	1.617	1	3.030
2020	5.034	2	7.218	1.937	1	3.669
2021	5.240	2	7.061	1.883	1	3.614
2022	4.378	1.5	6.661	1.834	1	3.561

**Gray shaded years indicates pre-legalization, green shaded years indicates post-legalization*

Road user types

Table 1 displays the count and share of cannabis-positive road users among everyone involved in a crash in which at least one person tested positive for cannabis between 2016 and 2022. This method is applied here to measure cannabis prevalence on the roads, and as a result of our no-fault crash analysis it is possible a road user other than a driver caused the crash to occur. Though drivers represented 64.4% of road users involved in a crash in which at least one person was cannabis-positive, they made up 72.2% of those testing positive. In a similar way, cyclists and pedestrians are both overrepresented as cannabis-positive road users relative to their broad involvement in a cannabis-positive crash. Passengers, on the other hand, are underrepresented. That is, passengers made up 30.9% of all road users involved in a cannabis-positive crash, with 21.2% of those actually testing positive. See **Appendix A** for a list of the annual rate of all road users involved in a crash for which at least one person involved later tested positive for cannabis.

*Table 1: Count and share of cannabis-positive road user type involved in a crash from 2016-2022 in Illinois**

	Driver	*Passenger*	*Cyclist*	*Pedestrian*
Count Can-Pos	2,683	787	83	162
Share of Can-Pos	72.2%	21.2%	2.2%	4.4%
Total Share Road User Type Involved	64.4%	30.9%	1.5%	3.2%

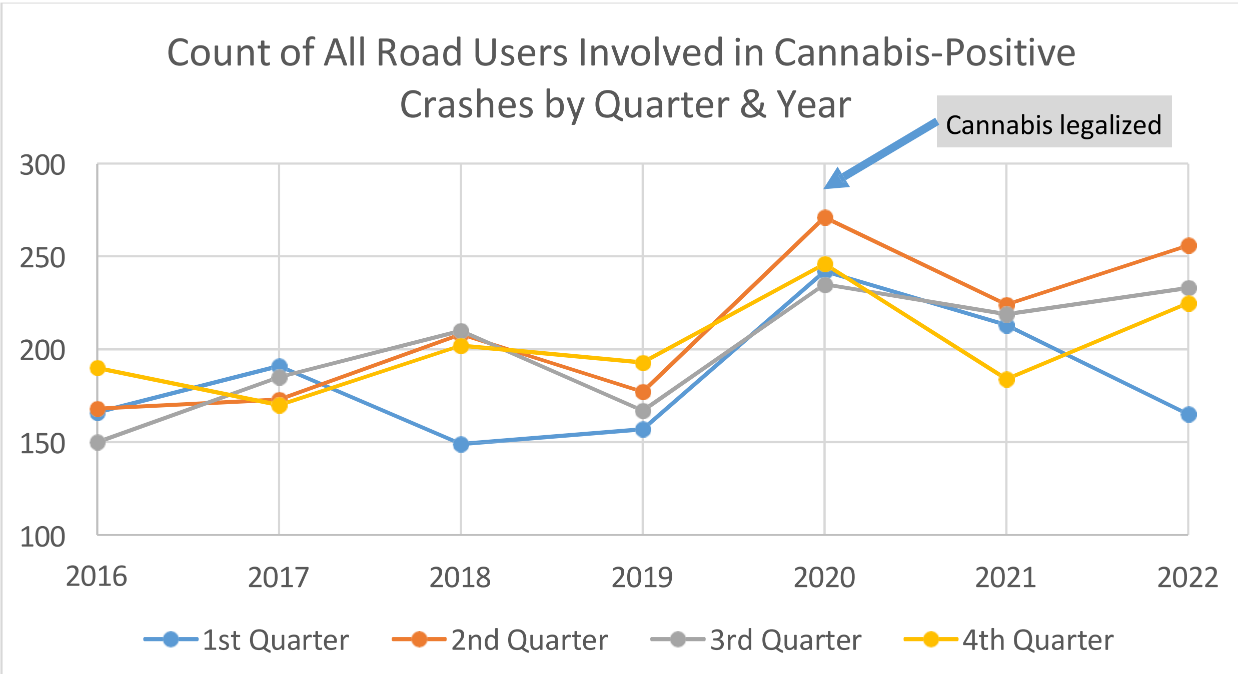
**P < 0.0001*

All road users involved

Figure 5 charts the count of all road users (drivers, passengers, pedestrians, and cyclists) involved in a motor vehicle crash in which one or more of those involved was diagnosed as cannabis positive by medical professionals in a hospital setting. The longitudinal data are displayed by quarter and by year for the seven consecutive years of 2016 through 2022. The four years of 2016 through 2019 represent linked crashes occurring prior to cannabis legalization taking effect in Illinois. While the three years of 2020 through 2022 are representative of linked crashes occurring post legalization.

As is discernible in **Figure 5**, the total annual count of those involved in cannabis-positive linked crashes has been increasing at least as far back as 2016, peaking in 2020 at nearly 1,000 such cases. While the years 2021 and 2022 saw significant yet diminished increases relative to 2020, those increases came at a faster rate compared to the pre-COVID years.

*Figure 5: Count of all road users involved in cannabis-positive linked crashes by quarter and year 2016-2022**

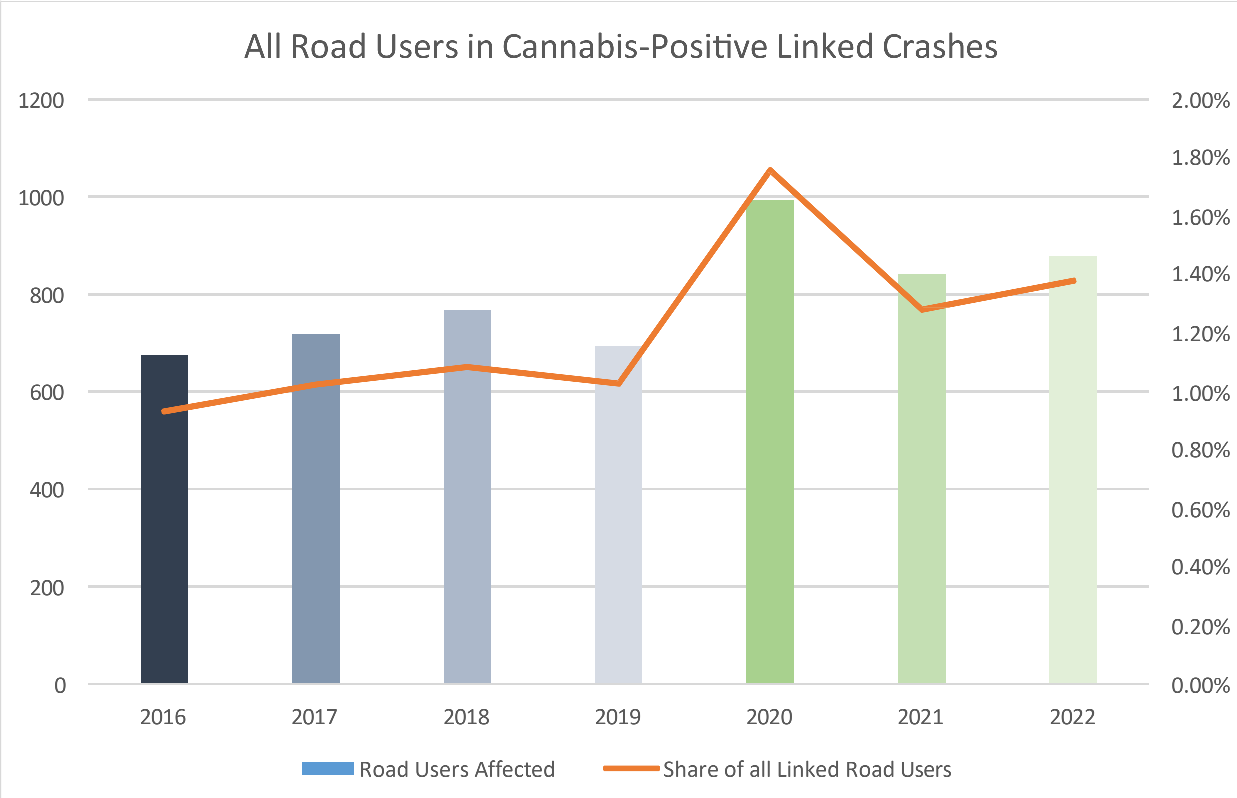


**Created by authors using linked data set; data are not seasonally adjusted*

The presentation of counts of incidents is one important part of the cannabis-positive crash analysis, **Figure 6** presents another important element of our analysis – the distribution of the share of incidents across time. The pre-legalization years of 2016 through 2019 averaged 714 linked cannabis-positive cases annually. In the outlier year of 2020, that number increased by some 39% (to 994 cases) compared to the previous four year average before seeing relatively modest (yet slightly accelerated) growth in 2021 and 2022. Also made visible by displaying the data as is done in **Figure 6** is that the relationship between the share of linked cannabis-positive crashes and the count of crashes was also abnormal. That relationship reverted to a more normal one in the intervening years of 2021 and 2022.

One potential explanation is that some of those inclined to engage in the risky behavior of taking to the roads following cannabis consumption are the same to take to the roads during a public health emergency. If this is true, then the share of cannabis-positive road users in 2020 was already elevated relative to a normal, non-health emergency year – since the risk averse were largely staying home. In other words, in this scenario, the denominator in the calculation of the share of crashes was smaller while the numerator either stayed about the same or slightly increased.

*Figure 6: Distribution of count and share of all road users involved in cannabis-positive crashes 2016 through 2022 in Illinois**



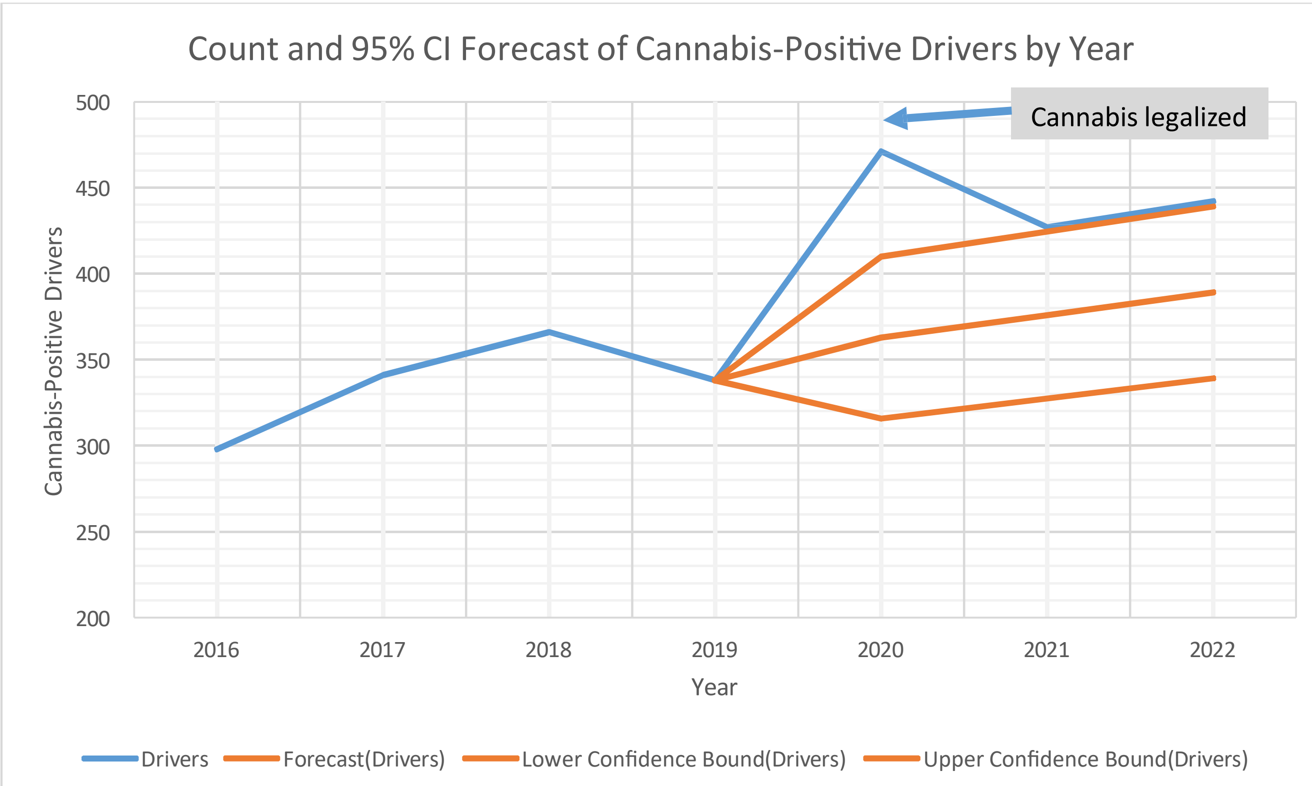
**Gray shaded years indicates pre-legalization, green shaded years indicates post-legalization*

Cannabis-positive drivers

To more completely capture the extent to which cannabis use on the roadways effects the traveling public, as done elsewhere, **Figure 5** includes all classifications of road users (Lee et al., 2021). The incidence of linked cannabis-positive crashes from 2016 through 2019 are used to estimate with 95% confidence the counterfactual – expected range of incident frequency for the succeeding years of 2020 through 2022 absent legalization. Presented only with **Figure 5** one may logically question whether a significant proportion of the increase in cannabis-effected road users is comprised of those with little to no agency or responsibility in the crash, the cannabis-positive passenger. That is, a single, cannabis-positive passenger involved in a crash involving many other, cannabis-negative, road users. However, **Figure 7** shows a similarly proportionate increase in cannabis-positive drivers involved in crashes beginning in 2020.

Figure 7 charts the count of cannabis-positive drivers involved in linked motor vehicle crashes between 2016 and 2022 in Illinois. In a similar way to **Figure 5**, cannabis-positive drivers have been steadily increasing since at least 2016 with a noticeable spike in 2020. The rate of growth slowed in 2021 and 2022 relative to 2020, yet the count of cannabis-positive drivers was slightly greater than forecasted by the upper bound of the 95% confidence interval.

*Figure 7: Cannabis-positive drivers involved in crashes**

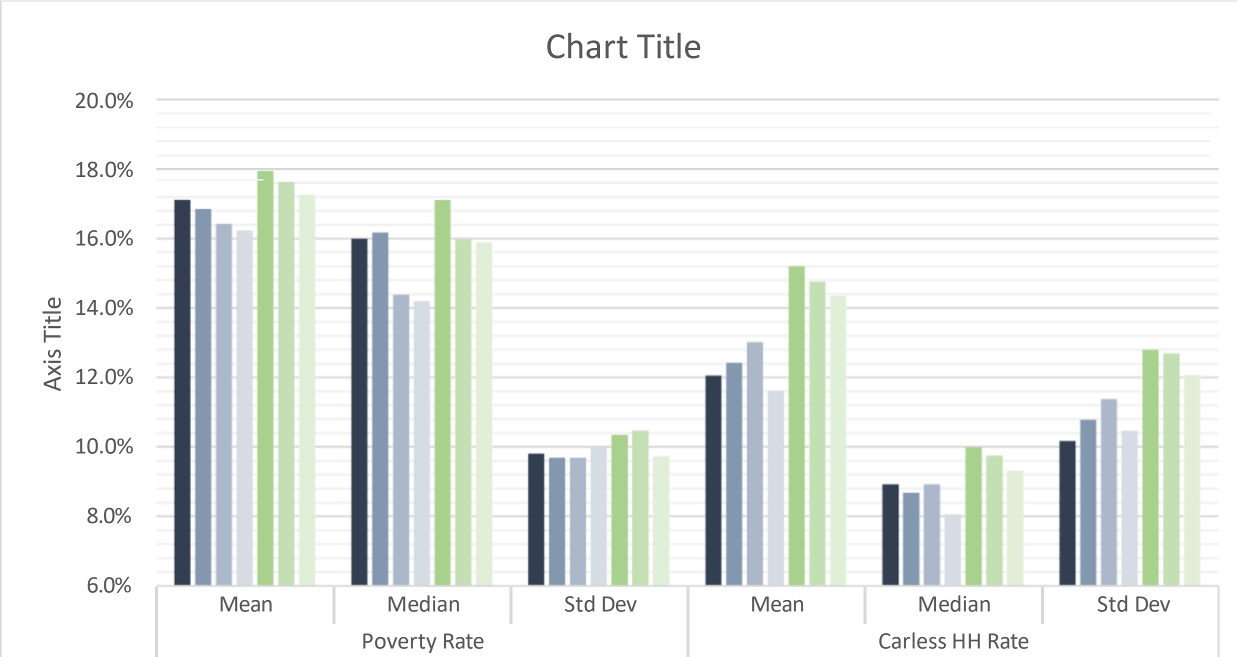


**Created by authors using linked data set; data are not seasonally adjusted*

Poverty, carlessness among those in cannabis-related crashes

Figure 8 shows both the poverty rate and rate of households with no car access at the zip code level for all individuals involved in a cannabis-positive motor vehicle crash. The average Illinois zip code poverty rate is 11.7%, and at about 17% the typical zip code of those involved in cannabis-positive crashes is more than five percentage points greater than the rest of the state. The average Illinois zip code carless household rate is 5.78%, at an average of 13.3% the typical zip code of those involved in cannabis-positive crashes is 2.3 times the rest of the state. So those involved in crashes in which at least one road user was cannabis-positive are far more likely to live in an impoverished zip code and/or a zip code with low car access. As demonstrated throughout this study through various other crash factors, poverty and carlessness rates were elevated among this cohort prior to cannabis legalization in 2020. Calendar year 2020 brought a marked increase in severity followed by a modest decline while maintaining their slightly elevated levels.

Figure 8: rates of poverty and carlessness at the zip code level among all road users involved in a cannabis-positive crash from 2016-2022 in Illinois,**,****



	Poverty Rate			Carless HH Rate		
	Mean	Median	Std Dev	Mean	Median	Std Dev
2016	17.1%	16.0%	9.8%	12.1%	8.9%	10.2%
2017	16.8%	16.2%	9.7%	12.4%	8.7%	10.8%
2018	16.4%	14.4%	9.7%	13.0%	8.9%	11.4%
2019	16.2%	14.2%	10.0%	11.6%	8.1%	10.5%
2020	17.9%	17.1%	10.3%	15.2%	10.0%	12.8%
2021	17.6%	16.0%	10.5%	14.8%	9.7%	12.7%
2022	17.2%	15.9%	9.7%	14.3%	9.3%	12.1%

**Y-axis begins at 6% to detail variation in bars; **Gray shaded years indicates pre-legalization, green shaded years indicates post-legalization; ***2019 ACS 5-Year Estimates*

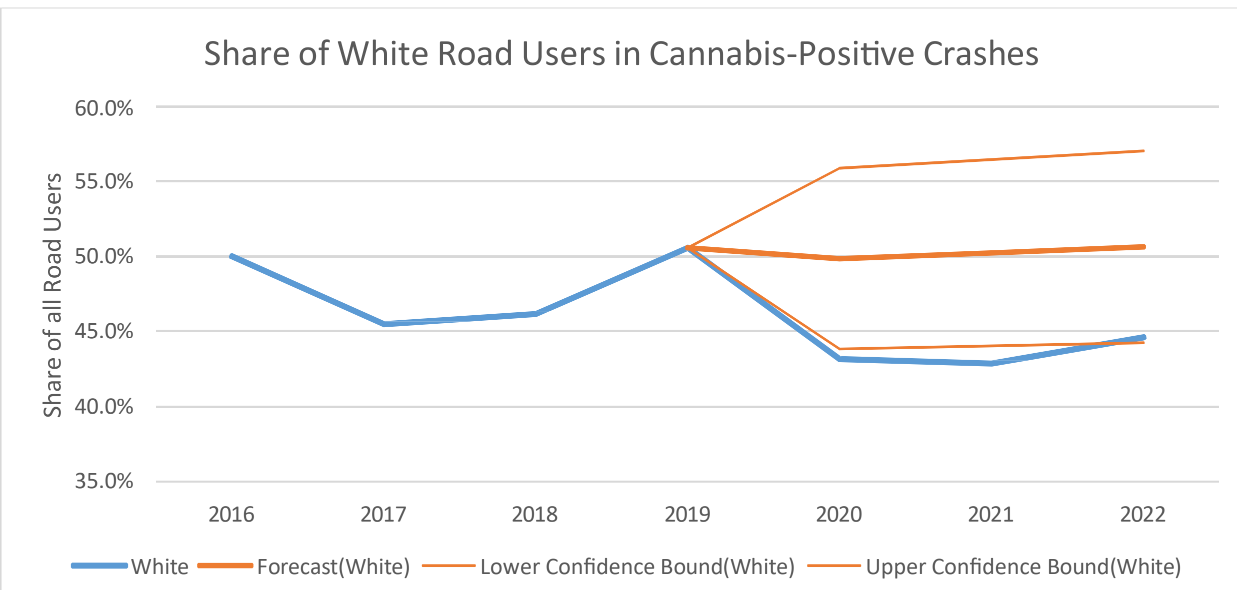
Distribution across race and ethnicity

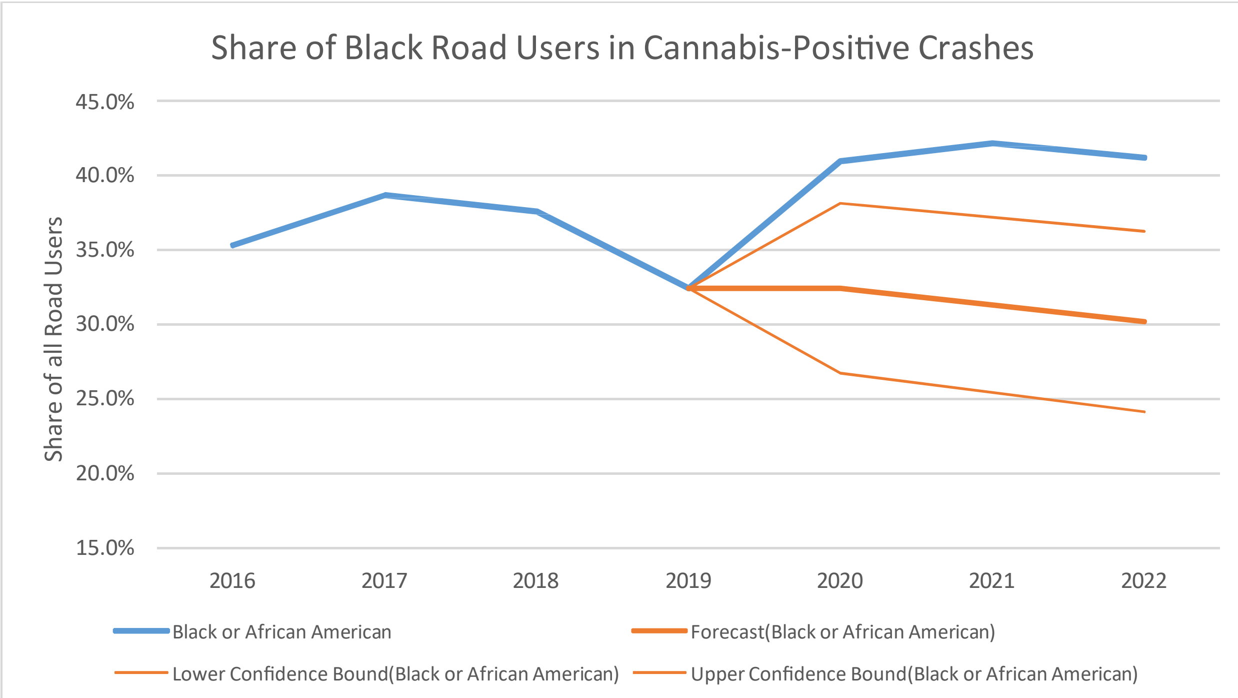
The series of charts in **Figure 9** demonstrate the distribution across race and ethnicity of the incidence of all road users involved in a crash in which at least one person was cannabis-positive between 2016 and 2022. Intuitively, as the share of either White or Black involvement goes up or down by year the other takes a fairly equal but opposite trajectory. Using a 95% confidence interval based on the years 2016 through 2019, we estimated the expected trends of the distribution of crash incidents for the years 2020 through 2022.

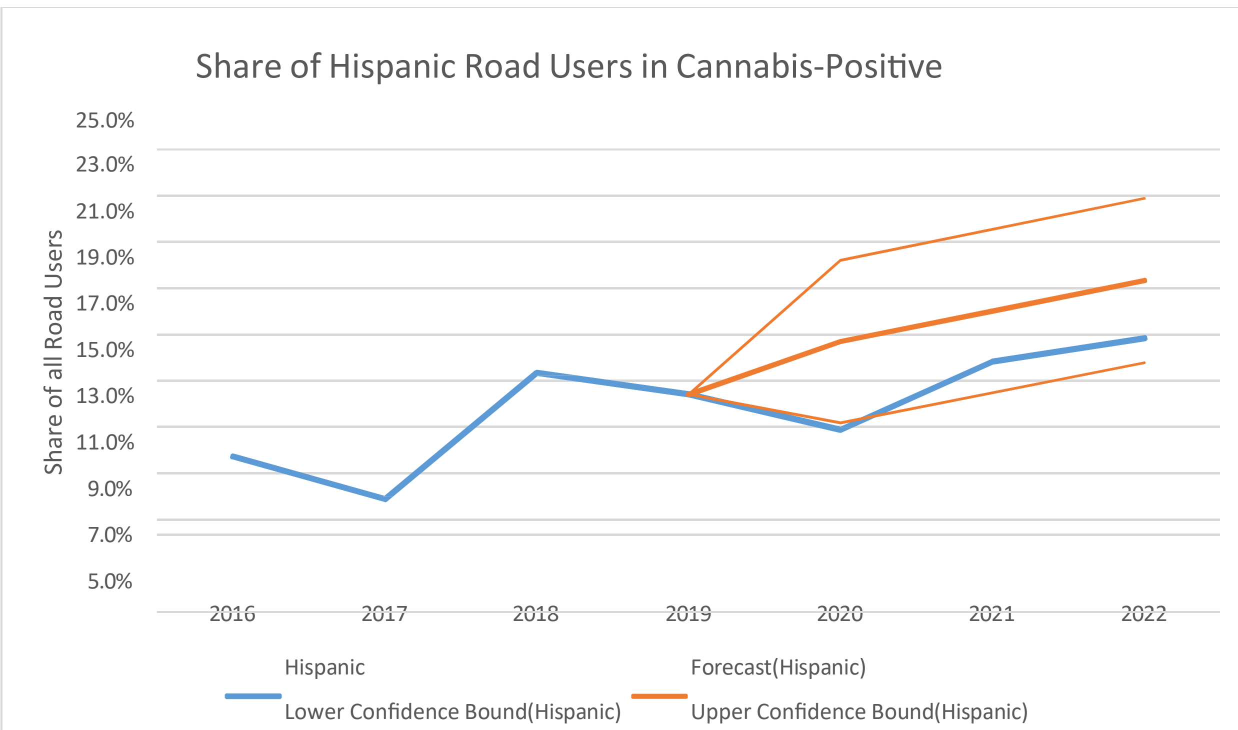
The share of White road users in cannabis-positive crashes fell to just below the lower boundary for 2020 and 2021, and rose slightly to just within the lower boundary in 2022. Stated differently, the share of White road users involved in a linked motor vehicle crash for which at least one person involved was cannabis-positive was reduced to unexpectedly low levels between 2020 and 2022. As with other factors analyzed and discussed within this report, this outcome, too, may be a side effect of Whites possessing the preponderance of white-collar, work from home-able jobs and careers at the onset of the COVID-19 pandemic in March 2020. So, as those employed in other "front line" roles and industries were recalled back to work – and necessarily back onto the roads – their risk exposure to crashes increased in kind.

The share of Black road users increased between 2020 and 2022 beyond the upper confidence interval boundary by between 2.8 and 5 percentage points. So, the share of Black road users involved in a linked motor vehicle crash for which at least one person involved was cannabis-positive increased to unexpectedly elevated levels between 2020 and 2022. The share of Hispanic road users in cannabis-positive crashes between 2020 and 2022 trended similarly to that of White road users over the same period. The share of Hispanic road users decreased to slightly below the lower interval boundary in 2020 before rising again in 2021 and 2022 to below the forecasted share but within the lower boundary. In a similar way to White road users, the share of Hispanic road users involved in a linked motor vehicle crash for which at least one person involved was cannabis-positive was reduced to unexpectedly low levels between 2020 and 2022. Though as other research has found, the "other" racial category may contain much of the true Hispanic population (Jarrín et al., 2020; Cohn et al., 2021).

*Figure 9 (and Supplemental Table 1): Distribution of share and 95% CI of race and ethnicity across all road users in cannabis-positive crashes**




Share of Black Road Users in Cannabis-Positive Crashes
Share of all Road Users
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
2016
2017
2018
2019
2020
2021
2022
Black or African American
Forecast(Black or African American)
Lower Confidence Bound(Black or African American)
Upper Confidence Bound(Black or African American)


Share of Hispanic Road Users in Cannabis-Positive
Share of all Road Users
25.0%
23.0%
21.0%
19.0%
17.0%
15.0%
13.0%
11.0%
9.0%
7.0%
5.0%
2016
2017
2018
2019
2020
2021
2022
Hispanic
Forecast(Hispanic)
Lower Confidence Bound(Hispanic)
Upper Confidence Bound(Hispanic)

Supplemental Table 1 for Figure 9

Race/Ethnicity	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
White	50.0%	45.5%	46.2%	50.6%	43.2% CI = [55.9%, 43.8%]	42.9% CI = [56.5%, 44.0%]	44.6% CI = [57.0%, 44.2%]
Black or African American	35.3%	38.7%	37.6%	32.4%	40.9% CI = [38.1%, 26.7%]	42.1% CI = [37.2%, 25.4%]	41.2% CI = [36.2%, 24.1%]
Other	12.6%	13.8%	13.4%	13.4%	12.2%	10.6%	9.9%
Hispanic	11.7%	9.9%	15.3%	14.4%	12.9% CI = [20.2%, 13.2%]	15.8% CI = [21.6%, 14.5%]	16.8% CI = [22.9%, 15.8%]

**P < 0.0001*

Modelling Cannabis-Positive Crashes

The interrupted times series (ITS) analysis has been widely applied to the study of the COVID-19 effect on various societal outcomes in addition to the relationship between cannabis legalization and motor vehicle crashes (Jones et al., 2019; Nazif-Munoz et al, 2020; Lee et al., 2021). Time periods during pre-legalization are commonly assigned membership within the pretreatment, or placebo, group. Periods occurring post-legalization are commonly assigned membership within the group receiving the treatment – a population-level intervention.

We were confronted with several options when designing our statistical model of crashes and cannabis; and several methods of specifying a response variable. Ultimately, in order to investigate our variables of interest, our response variable was modeled as a binary outcome with 1 representing a crash post-legalization and 0 representing a crash pre-legalization. Instead of predicting these two variables as outcomes we model the probability of the response variable taking one of these two values (Chatterjee & Hadi, 2006). As we are attempting to model the probability of an event occurring (legalization), and the event probability necessarily falls between 0 and 1, we must use a bounded statistical function. The logit model, more specifically the binary logistic model in which explanatory variables may be binary, categorical, or continuous, fits this bill and is applied here.

The logistic regression function, where π is the probability of legalization occurring while taking the form of the *odds ratio* as displayed in **Table 2**, takes the general form:

(Equation 1):

$$\frac{\pi}{1-\pi} = e^{\beta_0+\beta_1 x_1+\cdots+\beta_p x_p}$$

Table 2 displays the estimates of the fitted binary logistic regression model where the response variable reflects whether each cannabis-positive crash occurred pre – or post – legalization (social intervention at population scale). The model utilizes the complete sample of cannabis-positive drivers in an attempt to measure a potentially more direct effect on road safety. The response variable is structured as binary where a 1 represents the crash occurring post intervention and a 0 indicating a pre intervention crash. The β coefficient in **Table 2** represents the odds ratio calculated for each explanatory variable. An odds ratio (β) of greater than 1 implies the effect of an increased likelihood of the response variable being true, and those less than one suggest a decreased likelihood. An odds ratio of exactly 1 suggests no cross effects between the explanatory variable and the response variable, even though that explanatory variable may be estimated to significantly contribute to the model estimates.

In testing the specified model for variable endogeneity, the correlation matrix estimated some minor autocorrelation between the presence of various substances, like alcohol and opioids. It also estimated some minor autocorrelation between being male and not using safety equipment, along with other more intuitive interactions such as no safety equipment and more severe injury.

Model results

The model estimates that an increase of one cannabis-positive crash, measured annually per one billion VMT and aggregated at the county level, was associated with a 1.033 (0.033%) factor increase in the likelihood that the additional crash took place post legalization. Put another way, there was a statistically significant yet weak effect between additional cannabis-positive crashes and legalization throughout Illinois. The binary logistic regression model was able to predict that the post-legalization period tended to have more cannabis-positive crashes relative to the pre-legalization period. This finding is consistent with findings published by the Illinois Cannabis Project, which found an increase in drivers testing positive for cannabis who were involved in fatal crashes in 2020 (2023 Annual Cannabis Report). The Cannabis Project report found, using federal reporting data (Fatality Analysis Reporting System, FARS), an increase in cannabis-positive drivers by some 12 percentage points for the year 2020, it also reports a substantial drop in drug testing by 23 percentage points over the same period (2018 – 2020).

Table 2 shows that higher level maximum abbreviated injury score (MAIS) injuries are significantly correlated with cannabis-positive crashed drivers occurring post legalization. MAIS is a categorical variable on a scale of 0 through 6 indicating the most severe injury sustained by a patient. A score of 0 indicates no injury, a score of 6 indicates a maximum, unsurvivable injury. Cannabis-positive crashed drivers had a mean MAIS injury rating of 1.72 post legalization, and a mean of 1.32 pre-legalization.

Pre-legalization, females represented 28% of cannabis-positive crashed drivers. Post-legalization, that share increased to just over 32% - a trend correctly estimated by the model. Among cannabis-positive drivers, distracted driving (negative correlation), speeding (positive correlation), and being male (negative correlation) are each estimated to be significantly correlated with post legalization. However, the upper and lower boundaries of each 95% confidence interval of the associated coefficient straddle both sides of 1. This implies there is a greater than 5% chance that each of these variables has the opposite relationship with the response variable of the one reported in **Table 2**. It also suggests the statistical possibility that these three variables have no effect on the response variable – since a β of exactly 1 is within the 95% confidence interval.

Table 2: Binary logistic regression model results of cannabis-positive drivers involved in crashes in Illinois between 2016 and 2022

Variable	Significance	β (Coefficient)	[CI]
Cann.-Positive Crashes per 1 Billion VMT	*<0.0001*	*1.033*	*[1.021, 1.045]*
MAIS	*<0.0001*	*1.549*	*[1.392, 1.723*
Distracted	*0.056*	*0.632*	*[0.395, 1.012]*
Speeding	*0.053*	*1.225*	*[0.998, 1.505]*
Rural	0.457	1.092	[0.867, 1.375]
Night	0.453	1.083	[0.880, 1.332]
Medicaid	*0.002*	*1.441*	*[1.149, 1.808]*
Male	*0.084*	*0.820*	*[0.654, 1.027]*
Alcohol	0.176	0.743	[0.483, 1.142]
Cocaine	0.207	0.772	[0.517, 1.154]
Opioid	0.494	0.846	[0.525, 1.365]
Polysubstance	0.729	1.070	[0.729, 1.570]
No Safety Equipment	0.480	0.891	[0.646, 1.228]
Aggressive Driver Action	0.991	0	[0, 0]

Where $p < 0.10$ in italics; Cannabis-positive crashes counted in the county where they occurred aggregated annually; VMT = vehicle miles traveled; CI = 95% confidence interval; Nagelkerke $R^2 = 0.379$; MAIS = maximum abbreviated injury scale; See Appendix B for variable details

Discussion

Findings presented here suggest post-legalization periods tend to have higher rates of cannabis-positive drivers in crashes when aggregated annually and normalized per 1 billion VMT at the county level. While statistically significant, the effect appears to be weak. Hence, we reject the null hypothesis as stated at the beginning of this paper. However, it is not possible to decouple the effects of cannabis legalization from events transpiring related to the COVID-19 pandemic. From societal and familial stressors, to stay-at-home orders, and social unrest, the associated confounding factors are too numerous to control for in a statistical test.

As investigated and published elsewhere by this research team (Edwards, 2022), COVID restrictions led to a 13% reduction in VMT across Illinois and a 25% reduction in the number of people involved in a crash. Yet the share of linked fatal crashes grew from 0.139% in 2019 to 0.218% of crash victims in 2020. As that research shows, elevated rates of risky driving behavior in 2020 likely contributed to an increase in fatalities and severe injuries – including an almost doubling of the share of those un-belted or un-helmeted. Substance use in crashes also increased in 2020 by a factor of 1.8 across all intoxicants, including polysubstance use. It was also shown that crashes from COVID related restrictions had a disproportionate effect on the impoverished and minority groups. Many other research papers found similar increases in risky behavior on the roads, especially speeding (Doucette et al., 2020; Huang et al., 2020; Lee et al., 2020; Liao et al., 2020; Lin et al., 2021; Stiles et al., 2021). This all implies the increase in cannabis-positive crashes may have been part of a broader society wide increase in risky roadway behavior during the first COVID year.

Among many potential explanations for the cannabis-crash correlation is that more road users than what was typical tested cannabis-positive from THC lingering in bodily fluids following cannabis liberalization and the inevitable experimental period to follow. Following the initial effect of legalization, experimental behavior may have moderated, and though the increase was still measurable in linked crash data, the effect persisted to a lesser degree. Another possibility is that legalization reduced some portion of any stigma associated with cannabis use, clearing the way for patients to reveal consumption and providers to test for presence. Increased prevalence may also be due to expanding consumption options beyond smoke inhalation such as edibles, beverages, and vaping.

Gradual liberalization of cannabis regulations and metered opening of dispensaries across time might have helped dampen the effects of outright legalization. Still, despite fewer opportunities for cannabis-positive crashes (fewer crashes overall in 2020) the count of all linked road users involved and the count of cannabis-positive drivers increased. So, whether do to recreational legalization, the effects of COVID-19, or likely some combined effect, the prevalence of cannabis in crashes increased beginning in 2020. Yet, whatever the forces that were responsible for a marked increase in cannabis-related crash factors studied here seem to have begun a slow retreat through calendar year 2021 and 2022. Additionally, follow-up research is necessary to monitor these crash factors for calendar years 2023, 2024, and beyond.

Future research would benefit from a spatial analysis of the relationship between crash location and its proximity to cannabis dispensaries and the manner in which this may affect communities differently. As of writing, the Illinois Cannabis Regulation Oversight Officer records the names and locations of 175 dispensaries dispersed across the state – the majority of which do not serve medical patients. Community impact is especially important for those disadvantaged communities shown to have an elevated risk of involvement – the impoverished, low car access, and Black communities. A more nuanced analysis of the progression of cannabis liberalization from decriminalization to legalization for medical purposes through full legalization and the effect, lagged or otherwise, on motor vehicle crashes could also shed more light on any dampening effect of gradual implementation. Finally, supplementing hospital discharge data with additional medical records may provide access to currently unobserved cannabis-positive crashes. A preliminary analysis of linked crash and trauma records (those most severely injured) suggests linked trauma data do capture some cannabis-positive incidents not captured in discharge data.

Language in the 2021 Bipartisan Infrastructure Law (BIL) directs the National Highway Traffic Safety Administration (NHTSA) to draft regulation requiring new motor vehicles in the U.S. to be equipped with impaired driving prevention technology (United States Department of Transportation). Though NHTSA has no hard deadline for issuing the regulation and it is unclear how far the agency will take its authority. Important to note, impaired driving detection technology installed in motor vehicles does not need to be limited to the detection of the chemical presence of an intoxicating substance. The opportunity is present to improve upon the typical ignition interlock commonly installed for those with impaired driving convictions. Technology is available that detects any type of driver behavior or action that is deleterious to driving skills, like drowsiness caused by fatigue or even distracted driving. Yet even the toughest of regulations blocking impaired driving from occurring will do little to stop impairment among other road users like pedestrians, cyclists, and even passengers. Still, the implementation of such prevention technology would undoubtedly save human lives.

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Appendix

Appendix A: Cannabis-positive crashes involving all road users aggregated annually by county per 1 billion VMT

County	2016	2017	2018	2019	2020	2021	2022
Adams	13.51913	13.68107	9.694528979	17.58404784	17.2504442	20.08000549	10.04288723
Alexander	0	0	0	0	0	0	0
Bond	6.86359	0	0	0	0	0	0
Boone	0	1.675344	1.648843004	0	0	0	0
Brown	0	34.83193	17.46424323	0	0	0	0
Bureau	1.754	0	0	0	0	1.876996021	0
Calhoun	0	0	0	0	0	0	0
Carroll	0	0	0	0	0	7.239789705	0
Cass	0	0	0	0	0	0	0
Champaign	11.66768	17.69582	19.97712111	19.26908577	14.40584954	14.28228017	9.047166156
Christian	6.183201	3.153215	0	3.147974062	6.803188171	3.408958638	6.896027816
Clark	0	0	0	0	0	0	0
Clay	0	12.67526	0	0	0	0	0
Clinton	2.479789	2.355571	4.742948968	0	7.503816385	7.078167128	4.846113401
Coles	9.492334	11.19232	20.62981633	26.98089324	10.67485792	9.644862022	28.83751823
Cook	7.801987	8.551413	10.77679258	8.257201339	18.95115944	14.58457755	15.18030625
Crawford	0	0	0	11.89682764	6.487603448	18.19029155	12.26373591
Cumberland	0	0	0	0	0	0	0
DeKalb	13.41787	5.553356	7.880742188	8.275936913	16.9726053	1.247144199	5.767649118
De Witt	0	0	0	5.229000604	0	0	0
Douglas	0	0	0	0	0	0	0
DuPage	3.469805	5.620182	3.818798307	2.932281714	4.638319027	3.775042572	1.634981893
Edgar	0	0	0	0	6.827672889	6.482225023	0
Edwards	0	0	0	0	0	0	0
Effingham	0	1.357895	0	1.335453927	2.946372563	2.602610451	0
Fayette	0	4.298964	0	2.15292419	14.32539905	0	0
Ford	6.410939	12.0512	24.22579918	0	0	0	0
Franklin	3.732372	1.832115	1.830225608	0	8.813503546	0	1.966418658
Fulton	9.534984	12.93394	6.507420711	40.03028959	18.13020525	3.42751479	3.488710303
Gallatin	0	0	0	0	0	0	0
Greene	0	0	0	0	17.67590674	18.462611	0
Grundy	8.401175	0	2.65466074	4.135652148	8.934318841	7.250973151	1.436402711
Hamilton	0	0	0	24.34160078	0	0	47.476185
Hancock	0	10.00474	5.037226032	0	10.48909138	0	0
Hardin	0	0	0	0	0	0	35.19413773
Henderson	0	0	0	0	0	0	0
Henry	0	2.66652	2.701488657	2.704858603	0	2.797000772	0
Iroquois	0	0	0	9.753011213	0	0	0

Jackson	64.06174	41.08959	4.426933375	49.61707403	65.02979747	19.17469027	7.557311743
Jasper	0	0	0	0	7.84692415	0	0
Jefferson	1.337659	5.414157	1.325341441	0	9.17691375	1.252041844	3.930398105
Jersey	15.40022	0	5.230456092	0	38.2452333	45.75079177	20.76578914
Jo Daviess	0	0	0	0	0	4.380941778	4.470331778
Johnson	0	0	0	0	3.979330023	0	0
Kane	2.278775	4.74983	7.16445215	6.158769577	5.648226741	5.31714346	3.894432472
Kankakee	28.15343	16.68294	34.50794203	11.81884263	19.57929089	21.23410587	13.38906786
Kendall	0	2.48457	1.234987196	1.198414834	1.355628976	0	0
Knox	0	1.802921	0	0	9.8886811	1.847277766	1.908810812
Lake	8.847244	8.044264	7.037965392	7.854658371	6.798813949	9.836835845	8.474473536
LaSalle	0.728456	0	3.578257241	0	0	3.11578567	2.334706133
Lawrence	0	0	6.322178774	0	0	0	0
Lee	1.719465	1.654058	3.307021928	0	0	12.02343763	1.622425324
Livingston	0	0	0	0	8.174570086	0	0
Logan	0	3.552348	0	0	0	0	3.857082392
McDonough	3.858221	0	0	0	25.45299037	13.00293849	30.75505208
McHenry	0.416089	3.815902	7.622098023	4.941936181	8.857379483	0.840666581	1.640756667
McLean	0.546806	3.802082	1.086580858	1.112948809	1.872219682	0.587189925	3.488376977
Macon	9.590039	18.21002	6.447967992	3.200153461	7.1603242	4.549193672	11.28644799
Macoupin	0	0	0	0	2.634806148	0	0
Madison	6.887212	8.788042	10.82329375	6.06387386	3.671304553	2.106501369	12.50152778
Marion	0	0	3.931376935	4.001436083	0	0	0
Marshall	0	0	0	0	0	0	0
Mason	0	0	0	0	0	0	0
Massac	0	0	0	0	0	0	4.480410271
Menard	0	0	0	0	0	0	0
Mercer	0	0	0	15.19542764	0	0	0
Monroe	0	0	0	0	0	5.523041167	0
Montgomery	0	1.917416	0	0	4.505105205	2.045233706	2.044741542
Morgan	5.50113	0	0	2.830765165	0	0	0
Moultrie	0	0	0	0	0	0	0
Ogle	0	1.393143	1.409315998	0	6.203463064	0	7.371005701
Peoria	7.131978	6.718944	8.55708146	5.551935721	23.58162998	15.92511245	11.44427403
Perry	15.07084	0	0	0	5.902262523	11.06280017	5.602520834
Piatt	0	0	0	0	0	7.989579703	0
Pike	0	13.34455	0	0	0	0	0
Pope	0	0	0	0	0	0	0
Pulaski	0	0	0	0	7.975500856	0	0
Putnam	0	0	0	0	0	0	0
Randolph	0	11.21408	7.537009638	3.868086731	23.78098399	50.28472488	11.85016649
Richland	19.11228	0	0	6.859721077	0	0	21.01776642
Rock Island	6.068333	7.706637	10.87703757	7.530256779	4.189479086	4.618905429	6.908059957

St. Clair	2.877184	7.404339	5.683239747	3.552024842	2.159552044	3.082778441	11.33665853
Saline	4.256219	0	0	0	0	0	4.738612855
Sangamon	12.47089	9.546247	9.559832991	11.20112262	16.5829174	15.36265731	13.38581746
Schuyler	0	0	0	0	0	0	0
Scott	0	0	0	0	0	0	0
Shelby	3.928627	19.29399	7.881925415	31.80097045	0	0	0
Stark	0	0	0	0	0	0	0
Stephenson	7.877527	0	0	0	2.843804375	7.949401782	0
Tazewell	1.536407	2.306982	0.785300699	0.790658313	0	7.590846191	1.673157907
Union	0	0	0	0	4.333345309	0	4.044626467
Vermilion	4.14897	6.92722	0	5.869138903	4.854898862	1.49858622	7.522258
Wabash	0	0	0	0	12.07288881	0	0
Warren	0	4.72875	0	4.784401656	0	0	9.890106967
Washington	0	2.350211	0	2.267232223	0	2.385897642	0
Wayne	11.07398	3.789466	7.524396388	3.52763638	8.047859202	10.64792892	7.240697298
White	0	0	0	0	0	4.571255647	0
Whiteside	1.940988	1.899471	0	0	6.079592505	3.805570713	0
Will	6.886513	4.162245	6.570952353	6.675617288	8.295876407	5.488953016	6.574784808
Williamson	8.459281	17.2556	2.418179716	2.456348048	15.99970443	9.85597236	1.255997996
Winnebago	20.48883	10.36265	8.387080913	18.8286276	16.71334803	10.75623867	12.07076973
Woodford	0	0	0	0	0	0	0

Appendix B: Variable descriptions for binary logistic model

Variable	Data Type	Measure
Cannabis-Positive Crashes per 1 Billion VMT	Count	Cannabis-positive crashes per 1 billion vehicle miles travelled annually aggregated at county level
MAIS	Categorical	Most severe injury score
Distracted	Binary	Distracted or not distracted driver
Speeding	Binary	Speed a contributing crash factor or not
Rural	Binary	Built environment is rural or not
Night	Binary	Darkness of night or not
Medicaid	Binary	Driver medical care billed to Medicaid or not
Male	Binary	Male or not
Alcohol	Binary	Driver positive test or not
Cocaine	Binary	Driver positive test or not
Opioid	Binary	Driver positive test or not
Polysubstance	Binary	Driver positive for 2 or more substances or not
No Safety Equipment	Binary	Driver used safety equipment or not
Aggressive Driver Action	Binary	Driver aggressive action contributed to crash or not
Pre, Post Legalization*	Binary	Pre: 2016-2019 (0); Post: 2020-2022 (1)

**Response variable*