The Effectiveness of Graduated Driver Licensing in the United States

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(ABSTRACT)

This thesis has evaluated the effectiveness of GDL programs both in New Jersey and across the United States using several metrics. The New Jersey GDL program was analyzed because it is considered one of the most stringent programs in the country. It was found that GDL indeed reduces the per capita rate of crashes for teen drivers in New Jersey. However, no statistical difference was seen in the rate of fatalities in teen driver crashes. The per capita rate of violations for 16 and 17 year old drivers was lower after GDL, but the rate of point-carrying violations increased for 19 and 20 year old drivers who were licensed under GDL. The September, 2008 directive by the New Jersey Attorney General banning plea-agreements for teens significantly reduced the rate of violations further for 16 and 17 year old GDL drivers. The factors that led to teen crashes did not change in the United States after GDL. Teen drivers are still prone to distractions and inappropriate behavior while driving. Teen drivers also have higher rates of control loss and road departure crashes when compared to adults. Finally, it was found changes in the number teen driver crashes and fatalities are associated with similar changes in travel exposure. Teen crashes and fatalities have dropped with the implementation of GDL but teen VMT has also dropped. Graduated driver's licensing did not change the reasons for teen driver crashes. Also, it is likely that any reductions in the number of teen crashes or fatalities are associated with reductions in exposure and not changes in teen driver behavior.

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1. Background and Research Objectives

1.1 Introduction

In the United States since 2000 there has been an average of 5,300 fatalities in motor vehicle crashes involving a teen driver every year (FARS, 2000-2008). This accounts for 14.6% of all fatalities in motor vehicle crashes, yet, according to the Federal Highway Administration, teen drivers only account for 4.8% of all licensed drivers (FHWA, 2008). Furthermore, 4,900 teens die every year in motor vehicle crashes, comprising 11.7% of all fatalities. The Insurance Institute for Highway Safety (IIHS) reports that motor vehicle crashes are the leading cause of death for all persons aged 13-19 years old (IIHS, 2009). This is all despite a decline in overall teen fatalities over the last two decades as shown in Figure 2.

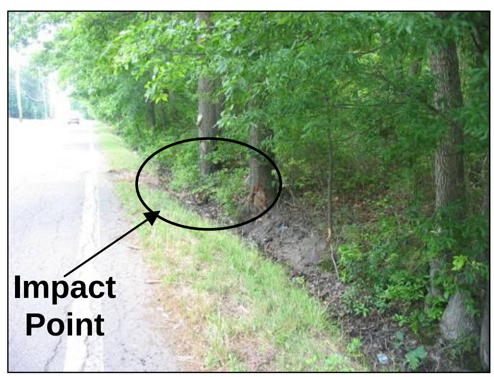

Figure 1. Teen Drivers are particularly at risk of crashes at night. In this New Jersey crash, a 17-year old driver struck a tree after leaving the road minutes before midnight. The impact fractured the lumbar spine of the teen's passenger (NASS/CDS Case 2005-04-070)

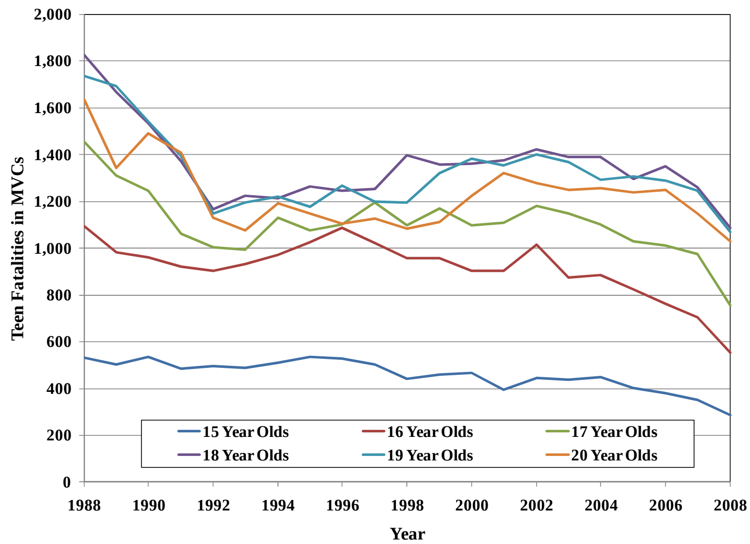

Figure 2. Teen Fatalities in motor vehicle crashes by age from 1988-2008 (FARS 1988-2008).

Teen motor vehicle crashes (MVCs) are believed to occur for a number of reasons ranging from driver inexperience, inability to deal with distractions, and a propensity for excessive risk taking among some teens (McKnight et al., 2003; Williams, 2003). Support of these findings has led to significant changes in the way that teens are exposed to driving.

1.1.1 Graduated Driver Licensing

Graduated driver licensing (GDL) programs have been widely enacted to reduce the crash involvement of teenagers. The fundamental theory behind GDL programs is that driving skills are acquired through practice and experience. Furthermore, novice drivers need time to accumulate the experiences necessary to develop their driving skills. Also, it has been demonstrated that driver responsibility increases with age. Thus, placing restrictions on younger drivers may lead to a reduction in accident rates for the affected age group (Preusser et al., 1998). The recognition of these teen-specific crash factors has lead to a basic GDL framework that is designed to address these issues. A typical GDL system includes three stages of licensure and various restrictions that gradually expose the new driver to more challenging situations. The following characteristics are employed in the majority of GDL programs worldwide:

Stage 1: Learner's Permit

- Supervised driving with a licensed driver
- 6-12 month duration

Stage 2: Provisional License

- Unsupervised driving
- 6-24 month duration
- Passenger Restrictions
- Night driving restrictions

Stage 3: Full Licensure

- Full driving privileges
- Barring no traffic violations / crashes while under GDL regulation

1.1.2 Teen Drivers

The universe of literature concerning GDL is large. The literature describes the complex issues associated with teen drivers and the effectiveness of policies to reduce teen crash risk. The large volume of research on teen driving has provided insight into the successes and failures of licensing systems worldwide and offered perspective about why teens are in particular need of intervention and training prior to licensure.

Naturally, teenagers have not reached a maximal maturity in many areas of life, including their approach to driving (Simpson, 2003). Furthermore, it has been shown that any beginning driver, regardless of age or maturity, possesses a higher crash risk as compared to more experienced drivers (Gregersen et al., 2003; Mayhew et al., 2003). Novice drivers possess the highest crash risk in the first 6 months of driving, and crash risk steadily declines with age (Mayhew et al., 2003). Both age (i.e. maturity) and experience have been identified as the largest contributors to increased teen crash risk (Williams, 1999; Mayhew, 2003; Mayhew et al., 2003; Simpson, 2003; Waller, 2003; Williams, 2003). This has created what has been labeled the "Teen Driver Paradox" (Simpson, 2003). Essentially, the teen driver paradox states that teen drivers require experience to develop their driving skills but increasing their exposure concurrently increases their chances of a crash. Deery (1999) reported that teen drivers are quite adept at acquiring basic driving skills. However, their limited experience does not allow them to develop the high-order cognitive abilities required to safely address many complex driving situations. Furthermore, Brown and Groeger (1988) reported that risk perception is controlled by two inputs: 1) information on the potential hazards and 2) information on a person's abilities to handle these hazards. A recent study examined the driving abilities of Finnish and Dutch novice drivers and found that 30-40% of novice drivers over estimate their own driving abilities (Mynttinen et al., 2009).

To mitigate these influences, GDL programs have been adopted by many countries and across the United States. The central focus is to gradually expose new drivers to increasingly difficult driving environments. Historically, many new drivers in the United States have gone through a driver training course that exposed them to driving environments under the supervision of a certified instructor. However, it has been found that traditional driver education courses alone have not been effective at reducing crash risk of new drivers (Mayhew et al., 1998). Instead, increasing the time that a teen is under direct supervision of a licensed driver can help to provide more situational training. This is addressed by enlisting the support and supervision of parents. The inclusion of the learner's permit in a GDL program can be considered as an apprenticeship-style solution to the need for increased supervision and training for a teen driver (Simpson, 2003). Under the skilled direction of an experienced driver, the teen (apprentice) gains event specific training that hones their abilities. Crashes under supervised conditions are relatively infrequent. Therefore, this has provided a lower risk, gradual, and exposure based training process for the new driver (Mayhew, 2003). In fact, Gregerson et al (2000) investigated the effects of a regulation change that lowered the minimum age for obtaining a permit (from 17 ½ to 16 years old) while maintaining the minimum age for full licensure (18 years old). It was shown that teen drivers who had a prolonged stay in the permit stage had lower crash rates after full licensure as compared to those who spent less time in the permit stage. Most importantly, it was found that the decrease in crash rate for licensed drivers who spent more time in the permit stage was not offset by an increase in supervised driving crash rate. Therefore, it was concluded that the experience gained through supervised driving was in fact producing better drivers after licensure, despite the fact that they began supervised driving at a younger age.

Presumably, once a teen driver has completed the learner's stage of licensure, they would be ready to face the challenges of driving with the knowledge and experience they have acquired.

However, other complications and distractions come with unsupervised driving, namely distractions from passengers and an increase in risky behavior. In fact, it has been shown that crash risk for teen drivers is the highest in the first month of unsupervised licensing (Mayhew et al., 2003). Efforts to minimize factors that may increase the likelihood of an unsupervised teen driver crash are an important component of GDL regulation. For instance, the number of passengers in a teen driver vehicle has been shown to be directly correlated to increased crash risk (Chen et al., 2000). As a result, restrictions on the number of allowed passengers for those licensed in the provisional stages has become an integral part of many GDL programs (Williams, 2003). Furthermore, a restriction on nighttime driving has also been shown to effectively reduce crashes during this time frame (Foss et al., 2001; Shope et al., 2004). While this may be largely due to a reduction in exposure, it may also allow the teen driver to gain more experience prior to undertaking the challenges associated with nighttime driving. It was found that while only 14% of the miles driven by a teen occurred between 9pm and 5:59am, these hours accounted for 39% of all teen MVC fatalities prior to GDL implementation (Williams et al., 1997).

The implementation of GDL programs is dependent on legislative change, and thus, potential obstacles. It has been suggested that resistance to the program may result from a belief that restrictions on teen driving are “unfair” to teen drivers who would not be considered high risk. However, many GDL proponents argue that, regardless of individual differences in maturity or propensity for risk taking, all beginner drivers are subject to increases in crash risk because of inexperience, thus necessitating a progressive licensing system (Simpson, 2003). Also, in a program that requires direct parental involvement, it is necessary that the parent be committed to the process. Interviews of both parents and teens have shown strong support for GDL (Williams et al., 2002). This will help to advance the process of enhancing the current GDL programs.

1.1.3 GDL in the United States

The licensing of new drivers in United States has been an enterprise controlled by the individual states. As a result, there has always been a large variation in the requirements and restrictions associated with licensing. Historically, many of the pre-GDL licensing systems included varied learners permit requirements. The learner's permit was instituted to increase the amount of supervised driving prior to full licensing. However many states had little or no requirements that dictated how long a driver had to remain in this stage (Simpson, 2003). In 1977, the National Highway Traffic Safety Administration (NHTSA) outlined their recommendations for a progressive system of licensing new drivers. This was intended to promote upgrades in the structure and requirements of state licensing programs. These recommendations were an improvement over many of the existing systems, however, they were never fully introduced in the United States (Mayhew, 2003; Simpson, 2003). In fact, it was not until 1987 when New Zealand became the first government to introduce what would be considered a modern GDL system (Langley et al., 1996). Ontario implemented the first GDL system in North America in 1994 and Florida was the first state to implement a modern GDL system in the U.S. in 1996 (Doherty, 1997; Ulmer, 2000). All states have updated their licensing laws since this time to include at least some features of a modern GDL program. However, significant differences exist in the requirements and restrictions associated with each state licensing laws. As a result, the Insurance Institute for Highway Safety (IIHS) has created a scoring system to evaluate each state's licensing laws based on what they consider an "Optimal" program (IIHS, 2009). The requirements for such a program are given below:

<u>IIHS Optimal GDL Requirements</u>

- 3 stages (Learners Permit (supervised), Provisional License (unsupervised), and Unrestricted License)
- Entry age of 16 years old
- 30-50 hours of supervised practice
- Restrict night driving at 9 or 10 pm
- No teen passengers / no more than one teen passenger
- Learners permit for at least 6 months
- Unrestricted licensure at 18 years old

1.1.4 GDL Regulation by State

The varying regulations included in the licensing laws of each state and Washington D.C. are included in the Table 1 (IIHS, 2009). IIHS has scored each of these GDL systems as either "Good (G)," "Fair (F)," "Marginal (M)," or "Poor (P)" based on how well they match up with the optimal system that IIHS has outlined. Currently, 35 states have a "Good" rating, 10 have a "Fair" rating, 6 have a "Marginal" rating and no state received a "Poor" rating.

Table 1. The GDL regulations of each state and Washington D.C. (IIHS, 2009).

		Learner Stage			Intermediate Stage Restrictions on Driving while Unsupervised			Minimum Age at Which Restrictions May Be Lifted	
IIHS Rating	**State**	**Min. Entry Age**	**Mandatory Holding Period**	**Min. Amount of Supervised Driving**	**Min. Age**	**Unsupervised Driving Prohibited**	**Restriction on Passengers (family members excepted unless otherwise noted)**	**Nighttime Restriction**	**Passenger Restriction**
G	*Optimal provisions*	*16*	*6 mo*	*30–50 hr*	*16, 6 mo*	*9/10 pm–5 am*	*No more than 1 teenage passenger**	*Until age 18*	*Until age 18*
G	Alabama	15	6 mo	30 hr (none with driver education)	16	Midnight–6 am	No more than 1 passengers	17	17
G	Alaska	14	6 mo	40 hr, 10 of which must be at night or in inclement weather	16	1 am–5 am	First 6 mo: No passengers	16, 6 mo	16, 6 mo
F	Arizona	15, 6 mo	6 mo	30 hr, 10 of which must be at night (none with driver ed.)	16	Midnight–5 am	First 6 mo: No more than 1 passenger younger than 18	16, 6 mo	16, 6 mo
G	Arkansas	14	6 mo	None	16	11 pm–4 am	No more than 1 passenger	18	18
G	California	15, 6 mo	6 mo	50 hr, 10 of which must be at night	16	11 pm–5 am	First 12 mo: No passengers younger than 20 (limited exception for immediate family)	17	17
G	Colorado	15	12 mo	50 hr, 10 of which must be at night	16	Midnight–5 am	First 6 mo: No passengers Second 6 mo: No more than 1 passenger	17	17
G	Connecticut	16	6 mo (4 mo with driver education)	40 hr	16, 4 mo	11 pm–5 am	First 6 mo: No passengers other than parents or driving instructor; Second 6 mo: No passengers other than parents, driving instructor, or members of immediate family	18	17, 4 mo
G	Delaware	16	6 mo	50 hr, 10 of which must be at night	16, 6 mo	10 pm–6 am	No more than 1 passenger	17	17

IIHS Rating	State	Min. Entry Age	Mandatory Holding Period	Min. Amount of Supervised Driving	Min. Age	Unsupervised Driving Prohibited	Restriction on Passengers (family members excepted unless otherwise noted)	Nighttime Restriction	Passenger Restriction
G	District of Columbia	16	6 mo	40 hr in learner's stage; 10 hr at night in intermediate stage	16, 6 mo	September–June: 11 pm–6 am Su–Th, 12:01 am–6 am Sa–Su; July–August: 12:01am–6 am	First 6 mo: No passengers; Thereafter, no more than 2 passengers	18	18
F	Florida	15	12 mo	50 hr, 10 of which must be at night	16	11 pm–6 am (age 16), 1 am–5 am (age 17)	None	18	—
G	Georgia	15	12 mo	40 hr, 6 of which must be at night	16	Midnight–6 am	First 6 mo: No passengers Second 6 mo: No more than 1 passenger younger than 21 Thereafter, no more than 3 passengers	18	18
G	Hawaii	15, 6 mo	6 mo	50 hr, 10 of which must be at night	16	11 pm–5 am	No more than 1 passenger younger than 18 (household members excepted)	17	17
M	Idaho	14, 6 mo	6 mo	50 hr, 10 of which must be at night	15	Sunset to sunrise	First 6 mo: Licensees 16 and younger can have no more than 1 passenger younger than 17	16	15, 6 mo
G	Illinois	15	9 mo	50 hr, 10 of which must be at night	16	Starts 10 pm Su–Th, 11 pm Fri–Sat, ends 6 am	First 12 mo: No more than 1 passenger younger than 20	18	17
G	Indiana	15, 6 mo	6 mo	50 hr, 10 of which must be at night	16, 6 mo (16, 9 mo without driver ed.)	First 180 days, 10 pm-5 am then 11 pm–5 am Su–F 1 am–5 am Sa–Su	First 180 days: No passengers	18	17 (17,3 mo. without driver ed.)
F	Iowa	14	6 mo	20 hr, 2 of which must be at night	16	12:30 am–5 am	None	17	—
G	Kansas	14	12 mo (eff 1/1/10)	25 hr, in learner phase; 25 hr before age 16; 10 of the 50 hr must be at night	16	9 pm–5 am (eff 1/1/10)	First 6 mo: No more than 1 passenger younger than 18 (eff 1/1/10)	16, 6 mo (eff 1/1/10)	16, 6 mo (eff 1/1/10)

IIHS Rating	State	Min. Entry Age	Mandatory Holding Period	Min. Amount of Supervised Driving	Min. Age	Unsupervised Driving Prohibited	Restriction on Passengers (family members excepted unless otherwise noted)	Nighttime Restriction	Passenger Restriction
G	Kentucky	16	6 mo	60 hr, 10 of which must be at night	16, 6 mo	Midnight–6 am	No more than 1 passenger younger than 20 unless supervised by a driving instructor	17	17
F	Louisiana	15	6 mo	35 hr	16	11 pm–5 am	None	17	—
G	Maine	15	6 mo	35 hr, 5 of which must be at night	16	Midnight–5 am	First 180 days: No passengers	16, 6 mo	16, 6 mo
G	Maryland	15, 9 mo	9 mo	60 hr, 10 of which must be at night	16, 6 mo	Midnight–5 am	First 5 mo: No passengers younger than 18	18	16, 11 mo
G	Massachusetts	16	6 mo	40 hr	16, 6 mo	12:30 am–5 am (between 12:30 am–1:00 am and 4:00 am–5:00 am the night driving and passenger restrictions are subject to enforcement;)	First 6 mo: No passengers younger than 18	18	17
F	Michigan	14, 9 mo	6 mo	50 hr, 10 of which must be at night	16	Midnight–5 am	None	17	—
G	Minnesota	15	6 mo	30 hr, 10 of which must be at night	16	First 6 mo: Midnight–5 am	First 6 mo: No more than 1 passenger younger than 20 Second 6 mo: No more than 3 passengers younger than 20	16, 6 mo	17
F	Mississippi	15	12 mo	None	16	10 pm–6 am Sun–Thu; 11:30 pm–6 am Fri–Sat	None	16, 6 mo	—
G	Missouri	15	6 mo	40 hr, 10 of which must be at night	16	1 am–5 am	First 6 mo: No more than 1 passenger younger than 19 Thereafter: No more than 3 passengers younger than 19	17, 11 mo	17, 11 mo
M	Montana	14, 6 mo	6 mo	50 hr, 10 of which must be at night	15	11 pm-5 am	First 6 mo: No more than 1 passenger younger than 18 Second 6 mo: No more than 3 passengers younger than 18	16	16

IIHS Rating	State	Min. Entry Age	Mandatory Holding Period	Min. Amount of Supervised Driving	Min. Age	Unsupervised Driving Prohibited	Restriction on Passengers (family members excepted unless otherwise noted)	Nighttime Restriction	Passenger Restriction
G	Nebraska	15	6 mo	50 hr, 10 of which must be at night (none with driver education)	16	Midnight–6 am	First 6 mo: No more than 1 passenger younger than 19	17	16, 6 mo
G	Nevada	15, 6 mo	6 mo	50 hr, 10 of which must be at night	16	10 pm–5 am	First 6 mo: No passengers younger than 18	18	16, 6 mo
F	New Hampshire	15, 6 mo	None	40 hr, 10 of which must be at night	16	1 am–5 am	First 6 mo: No more than 1 passenger younger than 25	17, 1 mo	16, 6 mo
G	New Jersey	16	6 mo	None	17	Midnight–5 am until 5/1/10; then 11 pm–5 am	No more than 1 passenger (household members excepted) until 5/1/10 when the exception will be limited to the drivers' dependents	18	18
M	New Mexico	15	6 mo	50 hr, 10 of which must be at night	15, 6 mo	Midnight–5 am	No more than 1 passenger younger than 21	16, 6 mo	16, 6 mo
G	New York	16	6 mo (eff 2/22/10)	50 hr, 15 of which must be at night (eff 2/22/10)	16, 6 mo	9 pm–5 am	No more than 1 passengers younger than 21 (eff 2/22/10)	17 (18 without driver education)	17 (18 without driver education)
G	North Carolina	15	12 mo	None	16	9 pm–5 am	No more than 1 passenger < 21; if a family member younger than 21 is already a passenger then no other passengers younger than 21 who are not family members	16, 6 mo	16, 6 mo
M	North Dakota	14	6 mo	None	16		—		
G	Ohio	15, 6 mo	6 mo	50 hr, 10 of which must be at night	16	Midnight–6 am (age 16) 1 am–5 am (age 17)	No more than 1 passenger	18	17
G	Oklahoma	15, 6 mo	6 mo	50 hr, 10 of which must be at night	16	10 pm–5 am	No more than 1 passenger	16, 6 mo (17 without driver ed.)	16, 6 mo (17 without driver ed.)

IIHS Rating	State	Min. Entry Age	Mandatory Holding Period	Min. Amount of Supervised Driving	Min. Age	Unsupervised Driving Prohibited	Restriction on Passengers (family members excepted unless otherwise noted)	Nighttime Restriction	Passenger Restriction
G	Oregon	15	6 mo	50 hr (100 hr without driver education)	16	Midnight–5 am	First 6 mo: No passengers younger than 20 Second 6 mo: No more than 3 passengers younger than 20	17	17
G	Pennsylvania	16	6 mo	50 hr	16, 6 mo	11 pm–5 am	None	17 (18 without driver ed.)	—
G	Rhode Island	16	6 mo	50 hr, 10 of which must be at night	16, 6 mo	1 am–5 am	First 12 mo: No more than 1 passenger younger than 21	17, 6 mo	17, 6 mo
M	South Carolina	15	6 mo	40 hr, 10 of which must be at night	15, 6 mo	6 pm–6 am EST, 8 pm–6 am EDT	No more than 2 passengers younger than 21 (driving to and from school excepted)	16, 6 mo	16, 6 mo
M	South Dakota	14	6 mo (3 mo with driver education)	None	14, 6 mo (14, 3 mo w/driver ed)	10 pm–6 am	None	16	—
G	Tennessee	15	6 mo	50 hr, 10 of which must be at night	16	11 pm–6 am	No more than 1 passenger	17	17
G	Texas	15	6 mo	20 hr, 10 of which must be at night	16	Midnight–5 am	No more than 1 passenger younger than 21	17	17
G	Utah	15	6 mo	40 hr, 10 of which must be at night	16	Midnight–5 am	First 6 mo: No passengers	17	16, 6 mo
F	Vermont	15	1 yr	40 hr, 10 of which must be at night	16	None	No passengers	—	16, 6 mo
G	Virginia	15, 6 mo	9 mo	45 hr, 15 of which must be at night	16, 3 mo	Midnight-4 am	First 12 mo: No more than 1 passenger younger than 18; thereafter, no more than 3 passengers younger than 18	18	18
G	Washington	15	6 mo	50 hr, 10 of which must be at night	16	1 am–5 am	First 6 mo: No passengers younger than 20 Second 6 mo: No more than 3 passengers younger than 20	17	17

IIHS Rating	State	Min. Entry Age	Mandatory Holding Period	Min. Amount of Supervised Driving	Min. Age	Unsupervised Driving Prohibited	Restriction on Passengers (family members excepted unless otherwise noted)	Nighttime Restriction	Passenger Restriction
G	West Virginia	15	6 mo	50 hr, 10 of which must be at night (none with driver education)	16	10 pm–5 am	First 6 mo: No passengers younger than 20 Second 6 mo: No more than 1 passenger younger than 20	17	17
G	Wisconsin	15, 6 mo	6 mo	30 hr, 10 of which must be at night	16	Midnight–5 am	No more than 1 passenger	16, 9 mo	16, 9 mo
F	Wyoming	15	10 days	50 hr, 10 of which must be at night	16	11 pm–5 am	No more than 1 passenger younger than 18	16, 6 mo	16, 6 mo

1.1.5 The STANDUP Act

The **S**afe **T**een **a**nd **N**ovice **D**river **U**niform **P**rotection Act (STANDUP Act) was introduced to the House of Representatives in April of 2009. The bill proposes that states that adhere to a minimum set of GDL regulations be awarded incentive grants. The minimum requirements include:

- Three stage licensing process (learner's permit, intermediate license, basic license)
- Minimum entry age of 16 years old
- Nighttime driving restrictions until full licensure at 18 years old
- Cell phone / texting while driving prohibited until full licensure at 18 years old
- Passengers restricted to no more than one non-family member passenger until full licensure at 18 years old, unless accompanied by a licensed driver over 21 years old.

Any state that adopts these regulations would be awarded an incentive grant for each of the three years following enactment. Currently, only New Jersey and Washington D.C. adhere to all of these regulations with their enacted GDL laws. However, many states have instituted regulations that include at least some of these recommendations.

1.2 Graduated Driver Licensing in New Jersey

Teen fatalities in New Jersey continue to occur at a rate of roughly 80 deaths per year despite the implementation of a Graduated Driving Licensing in 2001. In response to this unresolved issue, the state of New Jersey instituted a Teen Driver Study Commission (TDSC) to seek new methods to reduce both the number and severity of crashes involving novice drivers.

The New Jersey GDL program is considered to be one of the most progressive and stringent in the United States. It is comprised of three stages of licensure for new teen drivers: learner's permit at a minimum of 16 years of age; probationary license at 17 years old; and a basic license at 18 years old. Each phase carries restrictions which reduce novice driver exposure to risky situations, such as driving at night. In New Jersey, the learner's permit requires a minimum of six months of supervised driving. The provisional license allows unsupervised driving for one year, but carries several restrictions including a ban on driving between 11:01pm-5:00am, and limits on the number of passengers. At each stage, these restrictions are gradually lifted if the driver adheres to the GDL regulations until full driving privilege is reached. The New Jersey GDL has been given a "Good" ranking by the IIHS standards. The only IIHS recommended regulation that is missing from the New Jersey system is a requirement of at least 30 hours of supervised driving for drivers in the learner's stage. The New Jersey GDL system also lost a ranking point for a night-time restriction that occurs after 10 pm. The current specifications of the New Jersey GDL laws at the time of this report are the following:

1. **Learner's Permit (Supervised)**

- Requirements
  - Minimum age, 16
  - Display reflective decal on the license plate
  - Pass vision screening and written test
  - Complete 6 hour behind-the-wheel driver training (required for 16 year olds, optional for 17-20 year olds)

- Restrictions
    - Must be accompanied by an adult who is at least 21 years of age and has held a NJ driver license for at least 3 years
    - Limit of one, non-family member passenger; may transport as many family member passengers as there are seat belts in the vehicle
    - No driving between 11:01 p.m. and 5 a.m.
    - No use of hand-held or hands-free wireless, interactive devices (cell phones, iPods, video games)
    - Driver and all passengers must wear seat belts

2. Probationary License (unsupervised)

- Requirements
    - Minimum age, 17
    - Display reflective decal on the license plate
    - Complete all requirements of the learner's permit listed above
    - Hold learner's permit for a minimum of six months without suspensions or postponements
    - Pass road test
- Restrictions
    - Limit of one passenger, unless accompanied by a parent or guardian
    - No driving between 11:01 p.m. and 5 a.m. (waiver available for employment and religious activities and/or emergency situations)
    - No use of hand-held or hands-free wireless interactive devices (cell phones, ipods, video games)
    - Driver and all passengers must wear seat belts

3. Basic License (unsupervised, no restrictions)

- Requirements
    - Minimum age 18
    - Hold provisional license for a minimum of 12 months without suspensions or postponements
    - Complete all the requirements of the provisional license

A table that exhibits how the New Jersey GDL system compares to the GDL in Washington D.C. and the recommendations of IIHS and the STAND UP Act are given in Table 2.

Table 2. The GDL recommendations of IIHS and the STAND UP Act compared to those in place in New Jersey Washington D.C. (IIHS, 2009).

	Learner Stage			Intermediate Stage			Minimum Exit Age	
	Min. Entry Age	**Holding Period**	**Min. Supervised Driving**	**Min. Age**	**Night Restrictions**	**Passenger Restriction**	**Nighttime Restriction**	**Passenger Restriction**
IIHS	16	6 mo	30–50 hr	16, 6 mo	9/10 pm – 5 am	No more than 1 teenage passenger	18	18
STAND UP Act	16	-	-	-	None Specified	No more than 1 teenage passenger	18	18
New Jersey	16	6 mo	-	17	11pm – 5am	No more than 1 passenger	18	18
Washington, D.C.	16	6 mo	50 hr	16, 6 mo	11pm – 6am	No more than 2 passenger	18	18

1.2.1 Enhancements to the Current GDL Regulations

The TDSC report offered a series of recommendations to revise, update, and strengthen New Jersey's Graduated Driver Licensing (GDL) program. As a direct result of the 47 recommendations provided by the TDSC report, a number of legislative bills have been proposed and/or signed into law that allow for further enhancements to the current GDL regulations. This includes “Kyleigh’s Law,” named after Kyleigh D’Alessio, a 16 teen year old that was killed in a vehicle driven by a fellow teen. Changes to the New Jersey GDL requirements include a requirement that all permit and provisional license drivers display a reflective decal on their vehicle that identifies them as a GDL driver. This is meant to make it easier for law enforcement to identify teen drivers and monitor their behavior. Also, the nighttime restrictions for provisional license drivers were moved from midnight to 11 pm and the number of passengers was reduced to one, regardless of family affiliation, unless accompanied by a parent or guardian. All of these new regulations went into effect on May 1, 2010.

Other requirements that have been presented but are waiting for approval will require teen drivers to log 50 hours of supervised practice driving for those who participate in 6 hours of behind-the-wheel training. The proposed law would require 100 hours for those who do not participate in the behind-the-wheel training before receiving their provisional license. In addition, it has been proposed that the minimum length of time that a teen must hold a permit before being allowed to obtain a provisional license be extended from 6 months to 12 months.

Finally, a directive from the New Jersey Attorney General, Anne Milgram, eliminated plea agreements for GDL holders, effective September 17, 2008. It was found that many teen drivers had entered plea agreements after receiving traffic violations. Under a plea agreement, a fine was assessed but all points on the driver’s license were removed. This allowed teen drivers who were cited for a violation to circumvent rules that would have resulted in postponements in the GDL licensing process. It was thought that if teens were no longer able to avoid the GDL penalties associated with receiving a violation, they may become more conscientious drivers.

1.2.2 The Need to Evaluate New Jersey's GDL Law

Both the original GDL regulations and the subsequent enhancements were meant to improve teen driver safety and ability. However, as noted in recommendation 1.9 in the TDSC report, without an analysis of real world crash and traffic violation data, improvements based on GDL implementation are only speculative. Also, it would be sensible to establish the potential benefits of the enacted and proposed enhancements, including an analysis of the ban on plea agreements for GDL holders.

The benefits of the stringent New Jersey GDL may allow for an early evaluation of the STANDUP Act, prior to its enactment. At the time of this thesis, New Jersey and Washington D.C. were the only two jurisdictions in the United States that met or exceeded the STANDUP act minimum regulations. With the availability of New Jersey police reports and the Motor Vehicle Commission's (MVC) violations records, it is possible to identify the benefits that are unique to a more stringent licensing program. In particular, the effectiveness of the New Jersey GDL program, compared to other programs, may provide insight into the effectiveness of increasing the minimum age requirements for all stages and regulations.

1.3 Previous GDL Effectiveness studies

A number of research efforts that have highlighted the successes of the current GDL programs. Studies, both domestically and abroad, have shown reductions in crash rates associated with GDL regulations. It has been shown that the crash rates in the first year of restricted, unsupervised driving have been reduced by 14-24%. However, only a 3-6% reduction in crash rates in the first year of unrestricted, unsupervised driving has been identified (Foss et al., 2001; Rice et al., 2004; Fohr et al., 2005; Kirley et al., 2008). This indicates that the improvements in teen crash rates seen with GDL are most pronounced while the drivers are subject to the regulations of GDL.

Similarly, studies have shown reductions in the fatality rates of teen drivers as well. However, it has been found that the fatality rates amongst teens can vary by age. All studies that investigated the fatality rate for drivers in the first year of unsupervised driving who are subject to nighttime and or passenger restrictions showed a decrease in fatality rates of 15-57% with GDL implementation (Agent, 2001; Foss et al., 2001; Shope et al., 2001; Rice et al., 2004; Shope et al., 2004; Zwicker, 2006; Males, 2007). However, the fatality rates for teenage drivers who have graduated from the GDL programs are more mixed. For example, Males (2007) noted a decrease in fatality rates for 16 year old drivers but an increase in fatality rates for 18 year olds, resulting in an overall increase in fatality rates for all teen drivers under GDL regulation in California. Agent (2001) also found an overall increase in teen driver fatality rates from the pre-GDL period to the GDL era. However, it was found that the fatality rates of teen driver decreased for 16 and 18 year olds, while increasing for 17 and 19 year olds.

These studies have indicated that crash rates involving teens may have been reduced, but the severest crashes (i.e. fatal crashes) involving teen drivers may not have changed, particularly for those who have graduated from the GDL program. It is possible that the restrictions of GDL have reduced exposure and increased driver conscientiousness while subject to the regulations of the program. It is difficult, however, to determine if these effects translate into more conscientious or prepared drivers after graduation from GDL.

1.4 Need for Further Studies

While a considerable amount of research has been presented on the experiences of individual states, a national perspective, outside of review articles, has not been presented. An analysis of the factors that contribute to the heightened teen driver crash risk nationally has not been published. Most analyses of teen driver crashes with respect to GDL have focused on crash and fatality risk, but not on the changes seen in teen crash characteristics. In order to better understand how GDL has been effective and how it can continue to be improved, an analysis of teen crash types, severity, distractions, and causation factors is necessary. Furthermore, many regulations are included in GDL legislation, yet, because they tend to be implemented as a group, it is difficult to ascertain which of the regulations are effective. As a result, it is important to take advantage of opportunities that will help provide perspective on the effectiveness of these individual regulations, such as the threat of penalties associated with traffic violations and crashes. Also, the STANDUP is meant to strengthen the GDL regulations of most states in order to further increase their effectiveness. However, no research has been conducted that supports this expectation. An analysis of the New Jersey GDL program, which meets all of the

STANDUP act requirements, may help to provide insight into the benefits of a stricter GDL program, thus providing motivation for the act's approval. Finally, a concern with GDL programs is that they are more effective at reducing the crash exposure for teens rather than actually changing the driving behaviors and improving driver awareness. An analysis of changes in driving exposure for teen drivers will help to illuminate the overall contribution of exposure in the reduction in crash and fatality risk for GDL drivers.

1.5 Research Objectives

This dissertation explored the effectiveness and a number of possible improvements to the current GDL framework. A series of studies were performed aimed at addressing the effectiveness of the current GDL program in New Jersey as well the proposed GDL enhancements. Furthermore, a combined study of a number of GDL programs in the United States was performed to identify changes in crash causation factors and teen driver exposure. To address these topics, the following research objectives have been met:

1. Determined the availability of data sources for analyzing GDL effectiveness both in New Jersey as well as nationally.

2. Evaluated the effectiveness of the current GDL program in New Jersey in reducing crash rates and fatality rates.

3. Evaluated the effectiveness of the current GDL program in New Jersey in reducing traffic law violation rates.

4. Evaluated the effect of a directive eliminating plea agreements on crash, fatality, and violation rates for teen drivers in New Jersey.

5. Identified the residual teen-specific crash factors associated with GDL nationally including susceptibility to distractions and pre-crash scenarios.

6. Evaluated changes in driving exposure for teen drivers after GDL implementation to determine the extent that it plays in the reductions seen in crash and fatality risk for GDL drivers.

The culmination of these research objectives provides perspective on the effectiveness of New Jersey Graduated Driver's License regulations, both current and future, as well as an understanding of how Graduated Driver's Licensing has affected the type and severity of teen crashes in the United States.

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2. Review of Methodologies and Data Sources

2.1 Introduction

A number of studies have been conducted both in the United States and internationally on the effectiveness of Graduated Drivers License (GDL) legislation. A wide variety of methodologies have been employed to conduct these research efforts. The reasons for utilizing a particular method are often the result of the availability of a particular data source and the primary goals of the research project. For instance, a particular group may be interested in the reductions in the number of teen crashes per year as a result of GDL regulation while another group may be more interested in a reduction in fatalities associated with teen crashes. These situations would most likely require different data sources and statistical approaches. This chapter reviews the varying methods that have been utilized to investigate GDL effectiveness and teen crash characterization.

2.2 Approach

The differing approaches utilized in previous GDL effectiveness studies were identified and assessed for applicability to our specific research goals. For each method, a discussion of the data availability is included. This review guided the methods used in the effectiveness determinations for the New Jersey GDL program and an analysis of GDL from a national perspective.

2.2.1 Effectiveness Calculation

To compute the effectiveness of legislative changes such as GDL implementation, the populations of interest must be compared before and after the legislation went into effect. A major challenge with identifying changes in the characteristics associated with a legislative change is choosing suitable measures of exposure and performance. For the purposes of determining the effect of GDL implementation, changes in teen driver related events and characteristics for those who were licensed before GDL regulations and those licensed under the GDL program must be compared. These events can be referred to as performance metrics. Performance metrics could include crash counts, fatality counts, injury counts, traffic violations, or societal costs associated with teen drivers and teen driver crashes.

Normalizing metrics are necessary to provide a reference for the performance metric so that changes are provided with context. These can include temporal variables (e.g. years or months), population counts, driver licensing counts, or miles traveled. Furthermore, a normalizing metric can be used to highlight changes in a performance metric due to an inherent relationship between them. For instance, it may be reasonable to assume that changes in teen crash counts are related to changes in the number of licensed teens. As such, to express changes in a performance metric, it is necessary to couple it with an appropriate normalizing metric.

Exposure metrics are a class of normalizing metric that are more directly related to the travel of a driver (e.g. vehicle miles traveled or driver logged hours). Unfortunately, age-specific data of this nature is often unavailable for the population or time frame of interest. To account for this lack of available data, a technique known as normalization by induced exposure has frequently been used. Induced exposure requires that a normalizing population be an independent population that is exposed to the same environmental changes. For the purposes of a GDL effectiveness analysis, this generally involves normalizing the teen crashes by adult crashes. The general equation for induced exposure is given in Equation 1. It has been reported that this method rarely provides a truly independent exposure metric (Keall et al., 2009; Mendez et al., 2010). However, in the absence of reliable exposure metrics, this is often considered an acceptable approach that for canceling out non-GDL factors.

$$Induced\ Exposure = \frac{Teen\ Performance\ Metric}{Adult\ Performance\ Metric} \qquad \textbf{Equation 1}$$

Based on a review of the literature on GDL effectiveness analysis, the normalizing populations used to compute induced exposure are generally of an age range where the drivers were not subject to the GDL regulations (e.g. adults), but are assumed to be exposed to the same changes in driving environment (Ulmer, 2000; Foss et al., 2001; Shope et al., 2001; Ulmer, 2001; Rice et al., 2004; Shope et al., 2004; Fohr et al., 2005; Zwicker, 2006; Kirley et al., 2008).

2.2.2 Performance Metrics

A review of the literature and a discussion of the applicability of numerous performance metrics and how they relate to the determination of GDL effectiveness was conducted. The use of each metric in other studies is discussed in the following section.

Crash Counts

Based on a preliminary review of the literature, the number of crashes for a particular group is the most frequently used performance metrics for GDL studies. The most common source of this data are national survey datasets and state police reported crash databases (Langley et al., 1996; Ulmer, 1999; Bouchard, 2000; Begg et al., 2001; Sagberg, 2001; Lam, 2003; Males, 2007; Raymond et al., 2007; Ross, 2008). From these databases it is possible to compute the crash counts of teen drivers both before and after GDL implementation.

Fatal and Injury Crashes

Several studies have examined the effect of GDL not only on crash frequency, but also crash severity, i.e. annual fatality rates (Bouchard, 2000; Begg et al., 2001; Males, 2007; Ross, 2008), the number of casualties by licensing status and age (Lam, 2003), or the number of teen crashes resulting in hospitalizations (Langley et al., 1996). These methods provide a public health perspective on the effectiveness of GDL regulation.

Teen Traffic Violations

Comparing traffic violations counts of teens that fall under GDL restrictions with those who were not under the regulations can also be used as a measure of GDL effectiveness (Raymond et al., 2007). The assumption is that reductions in teen driver traffic violations for those under GDL regulation would indicate that safer and more responsible drivers are being produced as a result of the regulations.

Crash Type

Differences in crash type can be used to examine changes in how drivers react to driving situations. In particular, it can show the situations that produce teen crashes and the changes in susceptibility with the implementation of GDL. Furthermore, crash types associated with teen drivers can be used to guide future research related to the residual issues associated with teen drivers. Many studies have identified the crash factors that were teen-specific before GDL (Mayhew et al., 1986; Brown et al., 1988; Williams et al., 1995; Williams et al., 1997; Williams et al., 1997; Deery, 1999; McGwin et al., 1999; Chen et al., 2000; McCartt et al., 2003; McKnight et al., 2003; Simpson, 2003; Williams, 2003; Braitman et al., 2008; Madden et al., 2009). However, studies that compare the crash types for teen drivers before and after GDL implementation were not found.

2.2.3 Normalization Metrics

Normalizing metrics are used to provide context to changes in performance metrics. The use of each normalizing metric in other studies is discussed in the following section.

Population Data

Based on a preliminary literature review, census data can provide the size of age-specific populations and has been the most commonly used method for analyzing GDL regulation (Ulmer, 2000; Foss et al., 2001; Shope et al., 2001; Ulmer, 2001; Rice et al., 2004; Shope et al., 2004; Fohr et al., 2005; Zwicker, 2006; Kingham et al., 2008; Kirley et al., 2008; Ross, 2008). Normalizing by population provides metrics such as crashes/teen. This approach allows computation of the per-capita societal benefit of GDL regulation (Kirley et al., 2008). In the

United States, a full census is performed every ten years and population is estimated for each state for the non-census years. This information can be found on the United States Census Bureau's website and is available for public download (USCB, 2009). This was the source of New Jersey population data used in this study.

Driver Licensing Status / per licensed Driver

Normalizing by the population of teens only considers those teens that are old enough to drive. Not all teens that are old enough to drive are actually licensed to drive. Several studies have used then number of licensed drivers as a normalizing metric (Hyde et al., 2005; Kirley et al., 2008; Neyens et al., 2008; Ross, 2008). Reliable licensing counts are difficult to obtain, however. The Federal Highway Administration publishes an annual report of the number of licensed drives by age and state (FHWA, 2008). However, IIHS (2006) has reported that these numbers are unreliable, particularly for younger drivers.

Miles Traveled

Normalizing by the number of vehicle miles traveled is an effective method of accounting for exposure, but it is often hard to find accurate counts that are stratified by age or licensing status. Surveys stratified by age were used to determine kilometers traveled for drivers in Ontario (Doherty, 1997). Gregersen et al. (2003) also used surveys sent out to Swedish teen drivers in the various stages of the licensing process and requested that they log the travel distance and time that they spent driving and used this to account for driver exposure. The state of New Jersey maintains a log of annual vehicle miles traveled (VMT) on public roads and the information is available through the NJDOT website (NJDOT, 2009). However, the data is not stratified by age.

2.2.4 Statistical Approaches

A review of the different statistical approaches that have been employed by previous studies was conducted. The strengths of each method are outlined. Each approach generally utilized a rate or value derived from a rate to express changes seen for pre-GDL and GDL licensed populations. This includes basic rates calculated from performance and normalizing metrics, percent change, rate ratios, and odds ratios. More advanced methods for determining these rates include the use of a moving average, particularly when analyzing crash rates over months instead of years (Langley et al., 1996; Hyde et al., 2005; Zwicker, 2006; Males, 2007; Neyens et al., 2008). Also, some groups utilize a Poisson's regression technique to compute the relative risk associated with GDL implementation when count data is used, e.g. fatality, crash, or violation counts. This technique can weigh and adjust observed counts over time to account for confounding factors (Foss et al., 2001; Kirley et al., 2008). Furthermore, the Poisson's regression method allows for the computation of confidence intervals to be used for the determination of statistical significance. Finally, many studies have used control groups, a.k.a induced exposure, to normalize by the driving environment for all drivers.

2.3 Data Sources

This section describes the data sources, which are available for compiling the performance and normalizing metrics. A review of the applicability of each data source is provided. Subsequently, the applicability and availability of each data source will guide the GDL effectiveness calculations.

Table 3. Data sources for obtaining performance metrics and their application to GDL effectiveness calculations.

	Crash Counts	Injuries	Fatalities	Violations	Driver Performance
NJCRASH	X	X	X		
FARS			X		
MVC				X	
NASS/GES	X				X
AOC				X	
NMVCCS	X				X

Table 4. Data sources for obtaining normalizing metrics and their application to GDL effectiveness calculations.

	Population	Licensing	VMT
U.S. Census Bureau	X		
FHWA Highway Statistics		X	
NHTS			X

2.3.1 NJCRASH

The NJCRASH database is a collection of all police reported crashes in New Jersey from 1997-2009. The NJCRASH database contains information regarding the circumstances of the crash as well as occupant information, including injury and fatality counts. The format of the NJCRASH database was overhauled in 2001; however the data collected is largely the same. Unfortunately, the timing of the format changeover coincided with the year of GDL implementation in New Jersey. As a result, this formatting switch should be regarded as a possible confounding factor in any subsequent analysis. The two formats (1997-2000 and 2001-2009) are designed to largely provide the same information. An analysis of the 1997-2000 dataset revealed a number of data quality problems not seen in the 2001-2009 format. Specifically, the most glaring problems were associated with the existence of duplicate records, over reporting of fatalities in crashes as compared to independent sources, and vehicles without drivers. However, some of the problems were present in both formats. The efforts undertaken to correct these problems are outlined in Appendix A.

2.3.2 FARS

The Fatal Automotive Reporting System (FARS) is a database of all traffic related fatalities in the United States starting in 1975. The database is maintained by the National Highway Traffic Safety Administration (NHTSA) and includes all automotive related fatalities on public roadways where the person died of crash related injuries within 30 days of the crash. While the NJCRASH data contains information regarding fatalities, an analysis found that the fatality counts from the 1997-2000 format (pre-GDL) of NJCRASH are significantly larger than counts published from other data sources, such as FARS. This makes it difficult to use NJCRASH for calculating fatality rates when analyzing New Jersey GDL effectiveness with regard to teen fatalities. Fortunately, FARS can be used in place of NJCRASH for computing fatal crash counts.

2.3.3 MVC

The Motor Vehicle Commission (MVC) in New Jersey keeps a record of all traffic violations and related events for all drivers licensed in the state. Events in the system included warning notices for point accumulations, suspension scheduling, traffic violations, and crashes. We were able to gain access to a semi-sanitized sample of this dataset to be used for analyzing changes in violations for teen drivers. The dataset we obtained was a collection of all events that occurred from January 1, 1986 to March 20, 2010. This included basic driver record information e.g., gender and date of birth, followed by details corresponding to each event. The details of up to 100 events per driver record were provided. The dataset that we had access to was not a census of all driver records in the state, however. Instead, it was a collection of driver records for those who a recorded event after January 1, 1986. All drivers who had clean records from this date on were not included. Furthermore, this meant that the dataset was not suitable for determining the number of licensed drivers in the state. This dataset allowed for an investigation based on traffic violations for teen drivers in New Jersey. A review of the MVC dataset composition is provided in Appendix B.

2.3.4 AOC

The New Jersey Administrative Office of the Courts (AOC) maintains the citation records of drivers in the state. A collection of some records was obtained by our research team. The dataset that we obtained consisted of all amended violations in the state for November 1, 2004-November 30, 2007. Included in the dataset was the original violation code, amended violation code, the event date, and the court appearance date. This allowed us to perform an analysis of plea-agreement violation trends in New Jersey.

2.3.5 NASS/GES

The National Automotive Sampling System General Estimates System (NASS/GES) is a large representative sampling of all crashes in the United States maintained by NHTSA. The dataset is made up of roughly 60,000 police accident reports (PARs) annually from 1988-2008. All crash information from the PARs, including occupant information, vehicle information and crash information are electronically coded into a uniform dataset and made available for public download from the NHTSA website. The data comprises 400 police agencies across the United States, providing a large source of accident data to be used for general crash analysis. Each case in NASS/GES is weighted according to its representation of all crashes in the United States. This data was used to determine the national teen driver crash rates.

2.3.6 NMVCCS

The National Motor Vehicle Crash Causation Survey (NMVCCS) was a research study undertaken by NHTSA from 2005-2007. The dataset includes a national representative sample of crashes. The data collected focuses on the pre-crash events. The unique benefit of NMVCCS is the close relationship with law enforcement that allowed investigators to conduct on-scene evaluations of the crash with the physical evidence still present as well as interview crash participants at the crash site. Included in the dataset is a large set of variables that address the circumstances and distractions that lead to the crash. This dataset provides a uniquely detailed assessment of driver behavior prior to the crash event. Using this data, it was possible to establish the residual issues in teen driver crashes. Specifically, it was possible to determine what distractions led to teen crashes, what pre-crash scenarios led to teen crashes, and how teens reacted to challenging situations. In the end, this provided a framework from which future GDL enhancement policy can be derived by establishing the areas of concern that continue to lead to teen crashes.

2.3.7 U.S. Census Bureau

The United Census Bureau conducts a national census every 10 years and the counts are available from their website (USCB, 2010). Population estimates for all other years are also available. The census data is available both by age and state. This data was used as a normalizing population in several analyses.

2.3.8 FHWA Highway Statistics

The Federal Highway Administration (FHWA) publishes an annual report on the state of the highways within the United States. Included in this report are licensing counts from each state. These licensing counts are given by age. The data is reported by each state every year. However, the validity of the numbers has been questioned, particularly for young drivers (IIHS, 2006). In particular, large year-to-year fluctuations were seen for many states and there was considerable under reporting of licensure for teen drivers in many states. However, this is the best available source for National and New Jersey licensing counts. These counts were used as a normalizing metric in the following analyses.

2.3.9 NHTS

The National Household Travel Survey (NHTS), formerly known as the National Personal Transportation Survey (NPTS), is a study conducted roughly every 6-8 years to identify changes in driving frequency within the United States and with respect to certain demographics. The last three iterations of the survey were conducted in 1995, 2001, and 2009. The dataset is a collection of household travel surveys conducted over a year. Each household member is recorded and each one-way trip is recorded within a 24-hour period. Trips that were taken in personal vehicles, public transportation, or other modes of travel such as walking or bicycling were all included. Each household, person, and trip was assigned weights that represent their representation in the annual travel behaviors of all American drivers. Details maintained in the dataset include data such as trip distance and time, driver age, travel mode, trip time, and other demographic data.

The data from each survey year is publicly available from the NHTS website (FHWA, 2010). This dataset was used to compute the travel exposure for drivers from a national perspective. Exposure metrics included vehicle miles traveled (VMT), person miles traveled (PMT), and total travel time.

2.4 Conclusions

A literature review of previous GDL effectiveness studies provided insight into the best ways to proceed with the analysis of New Jersey's GDL regulations as well as the National GDL effectiveness. This review of the literature on GDL effectiveness and an analysis of the availability and applicability of each proposed method and data source were used to guide all subsequent GDL analyses.

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3. The Effectiveness of New Jersey's Graduated Driver's License Regulations in Reducing Teen Driver Crash and Fatality Rates

3.1 Introduction

The New Jersey GDL program is considered one of the most progressive and stringent when compared to other systems in place in the United States (Williams et al., 2010). Comparing the successes and limitations of the New Jersey GDL program to those from across the country can help to highlight the components that prove to be most successful in reducing teen crash and fatality rates. All States have implemented at least some form of a graduated drivers license program (IIHS, 2010). While the regulations can vary significantly by state, they tend to possess similar components. Most state GDL programs include a three stage licensing process with various restrictions that are lifted with the successful completion of the previous licensing stage. The graduated driver's license (GDL) regulations instituted by the state of New Jersey in 2001, like other GDL programs, are intended to provide teen drivers with a progressive system that allows for growth in their driving abilities through experience. The regulations are meant to limit exposure to more complicated driving scenarios. Specifically, the age at which full driving privileges are allowed is extended compared to previous licensing systems, the hours in which teens are allowed to drive are restricted, and the number of passengers allowed in a vehicle driven by a teen is also limited. These are all means intended to lessen the number of crashes and fatalities in vehicles driven by teens.

3.1.1 Previous Research

Studies, both domestically and abroad, have shown reductions in crash rates associated with GDL regulations. It has been shown that the crash rates, e.g. crashes per year or crashes per capita, in the first year of restricted, unsupervised driving have been reduced by 14-24%. However, only a 3-6% reduction in crash rates in the first year of unrestricted, unsupervised driving has been identified (Foss et al., 2001; Rice et al., 2004; Fohr et al., 2005; Kirley et al., 2008). This indicates that the improvements in teen crash rates seen with GDL are most pronounced while the drivers are subject to the regulations of GDL.

Similarly, studies have shown reductions in the fatality rates, e.g. fatalities per year or fatalities per capita, of teen drivers who are under GDL regulation. However, it has been found that the fatality rates amongst teens can vary by driver age. All studies that investigated the fatality rate of drivers in the first year of unsupervised driving showed a decrease in fatality rates of 15-57% with GDL implementation. However, the results regarding teen drivers who are no longer under the regulation of GDL laws are more mixed with some reporting increased fatality rates for older teens (Agent, 2001; Foss et al., 2001; Shope et al., 2001; Rice et al., 2004; Shope et al., 2004; Zwicker, 2006; Males, 2007). These studies have indicated that crash rates involving teens may have been reduced, but the most severe crashes (i.e. fatal crashes) involving teen drivers may not have changed, particularly with respect to those who have graduated from the GDL program.

3.1.2 Need for Further Study

New Jersey's GDL program is considered to be one of the most stringent and progressive in the country. Therefore, developing an understanding of the successes of the New Jersey GDL program can help illustrate any benefits of a more strict licensing system. However, to date, little research has been conducted to determine the successes of the New Jersey GDL program. A recent study performed by Williams et al (2010) performed a preliminary analysis of the New Jersey GDL regulations, however they only included data up to 2005. Nonetheless, the study reported crash and fatality reductions for teen drivers in New Jersey in the years immediately following GDL. Specifically, 16 year old drivers experienced a 43% reduction in crash rate, i.e. crashes per population, and 17 year old drivers experienced a 25% reduction in crash rate when normalized by adult crash rates and age-specific census counts.

The **S**afe **T**een **a**nd **N**ovice **D**river **U**niform **P**rotection Act (STANDUP Act), a United States House of Representatives bill introduced in April of 2009, proposes that states that adhere to a minimum set of GDL regulations be awarded incentive grants. Currently, only New Jersey and Washington D.C. adhere to all of these regulations with their current GDL programs. The STANDUP Act is meant to strengthen the GDL regulations of most states in order to further increase their effectiveness. However, no research has been conducted that supports this expectation. An analysis of the New Jersey GDL program, which meets all of the STANDUP act requirements, may help to provide insight into the benefits of a stricter GDL program.

Objective This study will determine the effectiveness of the New Jersey GDL program on reducing teen driver crashes and teen driver related fatalities and examine the possibility of using the New Jersey model as a surrogate for the STANDUP Act.

3.2 Data Sources

A number of characteristics associated with teen drivers in New Jersey will be compared. As a result, a broad perspective on the changes in teen driver performance associated with GDL implementation is provided. The following section will briefly describe the data sources that were used to compute the various effectiveness measures associated with GDL regulation in New Jersey with regard to teen crashes and teen crash related fatalities.

3.2.1 NJCRASH

The largest source of data for crashes in the state of New Jersey is the NJCRASH database provided by the New Jersey Department of Transportation (NJDOT). This publicly available database is a record of all police reported crashes in New Jersey from 1997-2009. The NJCRASH data is available in two separate formats: 1997-2000 crash years and 2001-2009 crash years. The format changeover coincided with the implementation of the GDL program. As a result, the formatting, and any differences directly related to the change in formatting were considered as possible confounding factors when comparing the licensing populations. This is of particular importance because the 1997-2000 crash data is known to have data quality problems. The problems associated with the 1997-2000 format and the efforts that were taken to correct them are outlined in Appendix A.

3.2.2 Fatal Automotive Reporting System (FARS)

The Fatal Automotive Reporting System (FARS) is a database of all traffic related fatalities in the United States starting in 1975. The database is maintained by the National Highway Traffic Safety Administration (NHTSA) and includes all automotive related fatalities on public roadways where the person died of crash related injuries within 30 days of the crash. This data was used to investigate the changes seen in the number of teen fatalities and fatal crashes involving teen drivers in New Jersey with the implementation of GDL.

3.3 Methods

The approach of this study was to compare teen crash and fatality rates before and after implementation of current GDL laws. The New Jersey GDL law went into effect on January 1, 2001. For this study, we investigated the changes associated with teen driver performance for 1997-2009. For a driver to be included in any of these analyses, they must have been licensed in New Jersey. This was to ensure that any derived effectiveness calculations was with respect to drivers licensed in New Jersey only.

3.3.1 Measuring Crash Rate

A major challenge in selecting a measurement of crash rate was identifying a suitable measure of exposure. We needed to normalize the number of crashes for the fact that the number of teen drivers on NJ highways is unlikely to have remained constant over the 1997-2009 time period. As shown in Figure 3, the population in New Jersey has grown and the number of vehicle miles traveled (VMT) has generally increased over this period (2008 was the last year of available VMT data). It was important to account for these changes when comparing crash rates across multiple years. In general, these trends may be accounted for by dividing the number of crashes by an exposure metric that is known to have changed over time.

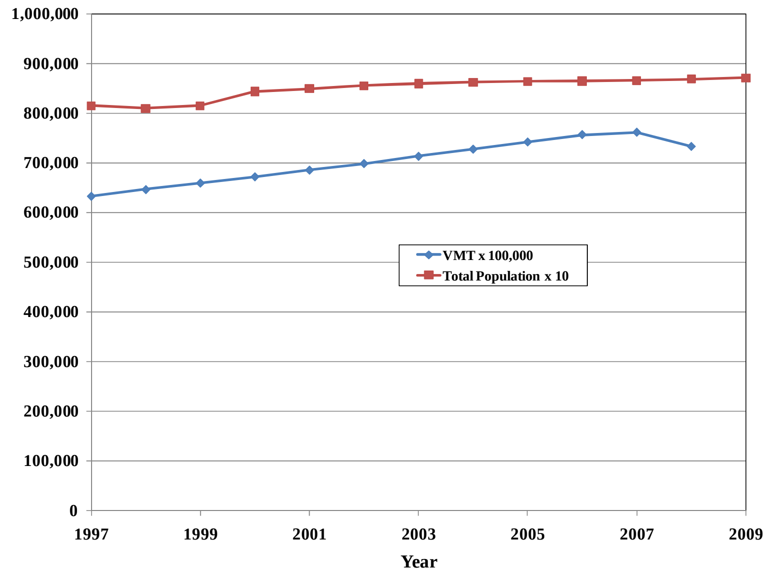

Figure 3. The annual population in New Jersey according to the United States Census Bureau and the annual total vehicle miles traveled (VMT) in New Jersey according to the New Jersey Department of Transportation (NJDOT, 2010; USCB, 2010).

While VMT is a widely used exposure measure, it was not possible to obtain data pertaining to individual age groups within New Jersey, e.g. teens (NJDOT, 2010; USCB, 2010). Another normalizing metric would be the number of licensed teen drivers in New Jersey. The Federal Highway Administration (FHWA) publishes an annual report of the number of licensed drivers by age and state (FHWA, 2008). Unfortunately, this data is reported to have errors (IIHS, 2006). According to the IIHS report, there were large variations in year-to-year violation counts for some states and there appeared to be issues associated with the reporting of the number of licensed teen drivers. Our inspection of the FHWA licensing dataset also found that 16 year old drivers were largely under reported in New Jersey. Nonetheless, normalizing teen driver events by the population of teens of driving age was used as a surrogate for the number of licensed drivers, but suffers from the fact that not all teens of driving age are licensed. Given that census data is the only available, reliable age-specific exposure metric for New Jersey teens, population counts were used in this study to provide context to the number of teen driver events.

3.3.2 Normalizing Ratio

A promising addition to these crash rate metrics is the ratio of teen driver crashes to the number of crashes involving adult drivers. This provides additional context to any changes in general crash frequency within the state that are unrelated to GDL. For the purposes of this study, the normalizing population consisted of an age range where the drivers were not subject to the GDL regulations, but were assumed to be exposed to the same changes in driving environment. The following metric was used:

$$Crash\ Ratio = \frac{Teen\ Crashes / Population}{Adult\ Crashes / Population}$$ **Equation 2**

For this study, the two age groups will be defined as follows:

- Teen Drivers: 16 – 20 years of age
- Adult Drivers: 35 – 55 years of age

The “Adult” age range was set at 35-55 years old for two reasons. First, the normalizing population should be exposed to the same driving environments and driving hazards as the teen driver group. For example, if the number of overall drivers and vehicles on New Jersey roads increases with time, it may influence environmental factors such as congestion and traffic speeds. We assumed that the adult and teen populations would be exposed equally to these changes. Secondly, the normalizing population must be isolated from the regulations of GDL to separate out its effects. At the time of our study, the 35-55 driving population included no drivers who were licensed under the GDL regulations.

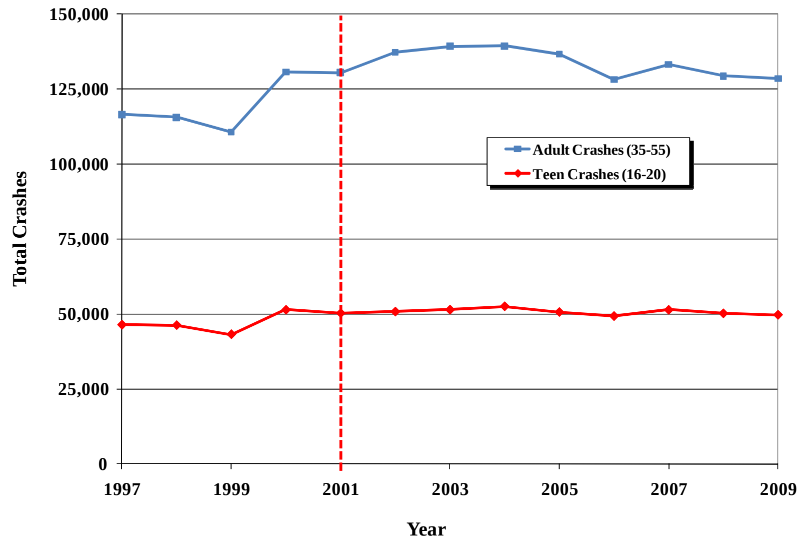

Figure 4. The total number of teen (16-20 yrs. old) involved crashes and the total number of adult (35-55 yrs. Old) involved crashes based on NJCRASH 1997-2009

Large fluctuations in annual crash counts were seen for all driver ages from 1997-2000 based on the NJCRASH data. However, it was assumed that the problems in this dataset were evenly distributed across all crashes, regardless of age. Thus, the effects of these inconsistencies were canceled out when normalizing the teen crash rates by the adult crash rates. As shown in Figure 4, the adult and teen crashes by year appear to follow the same uneven distributions by year, thus adding credibility to the assumption that the errors are evenly distributed across all driver ages.

3.3.3 Effectiveness Calculation

Effectiveness was computed based on changes in teen driver crash and fatality rates for time periods before and after GDL implementation. In each effectiveness calculation, case years 2000-2004 were removed. This accounts for two factors. First, this limits the influence that the GDL implementation may have had on teen licensing trends. This includes variations in teen licensing just prior to and just following GDL implementation. Uncharacteristic swings in licensing may be the result of teens trying to avoid the new, stricter regulations by licensing before the changes were instituted (Ulmer, 1999; Foss et al., 2001; Rice et al., 2004). Secondly, by defining the GDL period as 2005-2009, we ensured that only teen drivers who were licensed under the GDL regulation were included. The removal of the 2000-2004 case years produced two distinct populations of teen drivers: 1) 16-20 years olds licensed prior to GDL regulation (pre-GDL) and 2) 16-20 year olds licensed under GDL regulation (GDL era). All subsequent effectiveness metrics reported in this study directly compare the teen driver performance of both of these populations. Each effectiveness ratio is presented as normalized crash and fatality counts based on age-specific census data as described in Equation 2. The computed GDL effectiveness metrics comparing the pre-GDL and post-GDL periods are:

<u>Teen Crash Rate Analysis</u>

- % Change in the ratio of teen involved crashes vs. the number of adult involved crashes
- % Change in the ratio of single vehicle teen crashes vs. the number of single vehicle adult crashes.
- % Change in the ratio of teen drivers in crashes vs. the number of adult drivers in crashes

Teen Driver Fatal Crash Analysis

- % Change in the number of annual teen fatalities in crashes
- % Change in the ratio of teen driver fatal crashes vs. the number of adult driver fatal crashes
- % Change in the number of teen driver involved fatalities vs. the number adult driver involved fatalities

3.3.4 Poisson's Regression Analysis

In addition to comparing the teen/adult crash ratio before and after GDL implementation, Poisson's regression analyses were performed on the same dataset to determine the effect of GDL in the teen driver population and to obtain confidence limits to test for statistically significant changes in teen crash and fatality rates following GDL implementation on in New Jersey.

Poisson's regression is most often utilized to predict count data. In the case of the current study, the count of interest would be the number of crashes or fatalities in New Jersey. The general form of the Poisson regression equation can be described as a log-linear model, as shown in Equation 3. Here, "Y" is the count variable of interest, e.g. the number of crashes, and the coefficients, b, represent the contributions of other parameters, e.g. driver age group. However, because we did not expect the number of crashes to remain constant with time, a log offset was included in the model as shown in Equation 4. The offset in our model was the log of the exposure metric, i.e. age specific population. Following algebraic manipulation, the predictor variable now becomes a rate, i.e. the number of crashes per person, as shown in Equation 5.

$$log(Y) = \beta_0 + b_1(x_1) + \cdots + b_n(x_n)$$ **Equation 3**

$$log(Y) = log(Exposure) + \beta_0 + b_1(x_1) + \cdots + b_n(x_n)$$ **Equation 4**

$$log\left(\frac{Crashes}{Population}\right) = \beta_0 + Driver\ Age(x_{age}) + GDL\ Period(x_{GDL}) + Age/GDL(x_{age/GDL})$$ **Equation 5**

The predictor variables in the linear portion of the model were driver age (Teen or Adult), GDL time period (pre-GDL or GDL era) and an interaction variable between driver age and GDL time period. All statistical computations were performed using the SAS Statistical Software Package v9.2 (SAS, Cary, NC). The coefficients for each of these parameters were estimated through a least squares analysis. From this we were able to determine the relative rate associated with the interaction between GDL and teen drivers. Relative rates are computed by the exponentiation of the coefficient of interest from the linear equation. The form of the relative risk is shown in Equation 6. Due to the optimization of the log-linear model, this ratio is corrected for adult driver crash rates as well as teen driver exposure (i.e. population) trends. A relative rate of less than one reflects a reduction in crash risk for teen drivers after GDL implementation. Also, 95% confidence intervals were computed for each of the relative rates. To properly compute these confidence intervals, a negative binomial distribution was assumed to compute the variance within the crash populations and to account for overdispersion within the data distribution. Overdispersion occurs when the variation about a fitted value is greater than what is consistent with the Poisson distribution (i.e. the variance of the fitted variable is not equal to the mean). The negative binomial compensates for the level of overdispersion within the model and computes the variance accordingly (Berk et al., 2007).

$$Relative\ Rate = \frac{\left(\frac{Teen\ Crashes}{Population}\right)_{GDL-Era}}{\left(\frac{Teen\ Crashes}{Population}\right)_{Pre-GDL}} \quad \textbf{Equation 6}$$

3.3.5 Top 12 Counties

Based on a data quality analysis of NJCRASH, it was found that the problems from the 1997-2000 format were not evenly distributed across all counties in New Jersey. As a result, we hypothesized that some counties may have "better" data than others. Furthermore, conversations with NJDOT representatives has revealed that crash reporting is performed on the county level and that in fact, certain counties were speculated to be inconsistent in their reporting methods and completeness. To locate these counties with particularly good data quality, a ranking scheme was developed. Each county was ranked based on the following two metrics for determining data consistency and quality:

- Annual %-change in crash counts by county
- Annual %-difference in NJCRASH fatality counts vs. FARS Fatality Counts

Each county was ranked where by the counties with the smallest values for each of these fields are assigned the lowest ranking value. The combined ranking was the sum of both rankings. The 12 counties with the lowest combined ranking were considered the "Top 12" counties and comprise what will be referred to as the 12-county subset. Presumably, these counties have notably better data completeness in the 1997-2000 format.

3.4 Results

Each effectiveness calculation offers a different perspective on changes associated with GDL implementation. The results are presented in the following section.

3.4.1 Teen Crash rates

A distribution of all teen crashes from 1997-2009 are given in Figure 5. The purest measure of changes in teen driver crash risk after GDL implementation may be the percent change in single vehicle crashes. Generally, single vehicle crashes are presumably the result of decisions made primarily by one driver, thus indicating the purest measure of teen driver ability. An analysis of teen crash rates based on the NJCRASH data is also given below. The percent difference for each effectiveness metric comparing the two time periods was calculated and is given in Table 5.

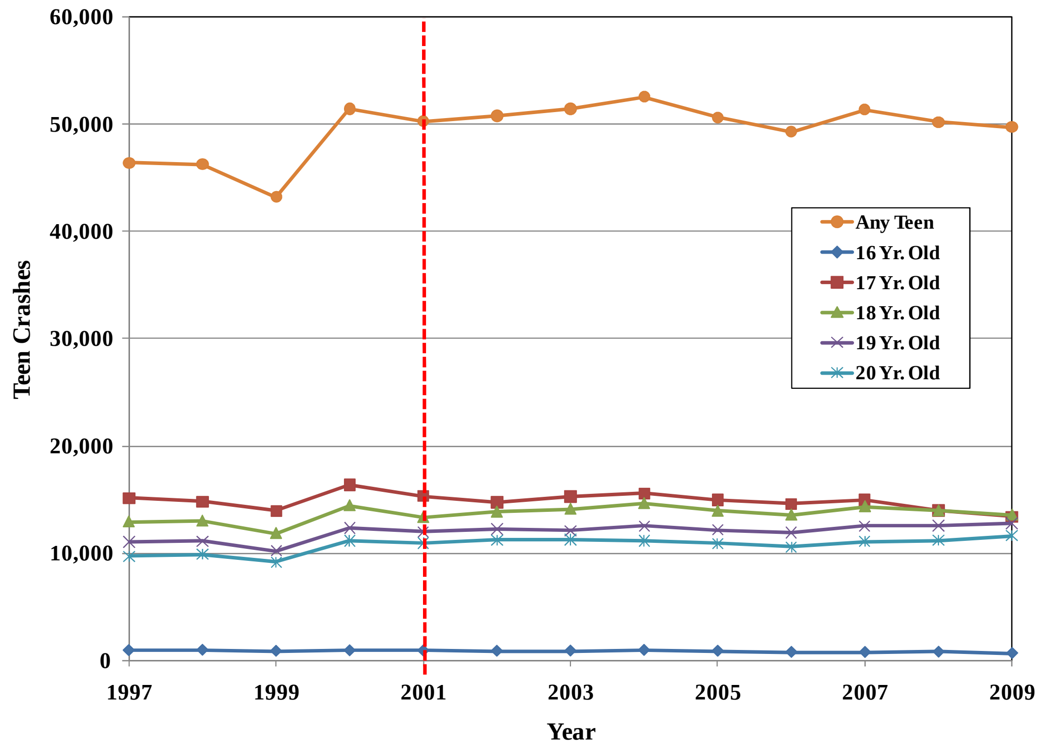

Figure 5. Distribution of teen driver crashes by year (NJCRASH 1997-2009).

Table 5. Changes in average crash ratios and driver count ratios by age based for teen drivers involved in crashes from NJCRASH 1997-1999 and 2005-2009.

	16 Yr Old	17 Yr Old	18 Yr Old	19 Yr Old	20 Yr Old	16-20 Yr Old
Teen Involved Crash / Adult - No Teen Involved Crashes (Norm. by Census)	-29.8%	-18.8%	-8.2%	9.2%	4.0%	-6.6%
Teen Single Vehicle Crash / Adult Single Vehicle Crash (Norm. by Census)	-34.0%	-27.3%	-14.3%	7.4%	1.9%	-11.9%
Teen Drivers / Adult - No Teen Drivers (Norm. by Census)	-29.3%	-17.0%	-6.9%	10.5%	4.9%	-8.3%

Table 6. Ranking New Jersey counties based on the average annual change in crash counts from NJCRASH 1997-2000 and the average difference in fatalities counts from NJCRSAH 1997-2000 compared to FARS 1997-2000.

County Rank on Data Quality				
	Avg. % Change in Annual Crash Counts	Avg. % Diff. in Fatalities vs. FARS	Ranking Total	
Atlantic	**2**	**1**	**3**	*
Bergen	10	17	27	
Burlington	**15**	**3**	**18**	*
Camden	**6**	**7**	**13**	*
Cape May	**14**	**4**	**18**	*
Cumberland	**20**	**2**	**22**	*
Essex	19	20	39	
Gloucester	16	10	26	
Hudson	13	18	31	
Hunterdon	12	11	23	
Mercer	**8**	**14**	**22**	*
Middlesex	**1**	**15**	**16**	*
Monmouth	**4**	**9**	**13**	*
Morris	**9**	**13**	**22**	*
Ocean	**7**	**6**	**13**	*
Passaic	**3**	**19**	**22**	*
Salem	21	5	26	
Somerset	11	16	27	
Sussex	18	8	26	
Union	**5**	**12**	**17**	*
Warren	17	21	38	

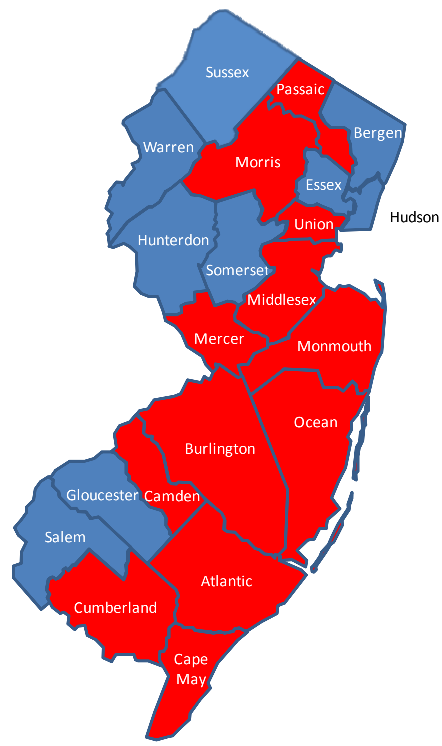

Table 7. Changes in average crash ratios and driver count ratios by age for teen drivers involved in crashes from the 12-County subset of NJCRASH 1997-1999 and 2005-2009.

	16 Yr Old	17 Yr Old	18 Yr Old	19 Yr Old	20 Yr Old	16-20 Yr Old
Teen Involved Crash / Adult - No Teen Involved Crashes (Norm. by Census)	-28.4%	-19.8%	-5.3%	13.5%	8.0%	-7.9%
Teen Single Vehicle Crash / Adult Single Vehicle Crash (Norm. by Census)	-34.8%	-29.3%	-14.1%	10.8%	5.1%	-9.4%
Teen Drivers / Adult - No Teen Drivers (Norm. by Census)	-27.9%	-18.1%	-3.9%	14.8%	9.0%	-13.4%

3.4.2 Top 12 County Analysis

To circumvent some of the problems in the 1997-2000 NJCRASH format, a ranking scheme was be developed to include only the top 12 counties based on data quality and consistency. The individual county rankings are presented in Table 6. The top 12 counties are indicated with a '*'. GDL effectiveness rates were computed based on crash records from these counties. An analysis of teen crashes in the top 12 counties based on the ranking scheme is presented in Table 7.

3.4.3 Poisson's Regression Analysis

The results from the Poisson's regression analysis for both the all county and 12-county subset are given in Table 8 and Table 9. Each table gives the relative rate and 95% confidence intervals for all crashes involving a teen driver, single vehicle teen driver crashes, and the number of teen drivers in crashes.

Table 8. Crash relative rates for teen (16-20 yrs. old) drivers involved in crashes based on a Poisson's Regression analysis of NJCRASH 1997-1999 and 2005-2009.

NJCRASH 1997-1999, 2005-2009			
Age	**All Teen Crashes** **RR** (95% CI)	**Single Vehicle Teen Crashes** **RR** (95% CI)	**Teen Drivers in Crashes** **RR** (95% CI)
16	**0.70** (0.63-0.78) *	**0.66** (0.58-0.76) *	**0.69** (0.61-0.77) *
17	**0.81** (0.75-0.88) *	**0.73** (0.67-0.79) *	**0.81** (0.74-0.88) *
18	**0.92** (0.86-0.98) *	**0.86** (0.80-0.92) *	**0.90** (0.84-0.97) *
19	**1.09** (1.03-1.16)	**1.07** (1.02-1.14) *	**1.07** (1.01-1.14) *
20	**1.04** (0.98-1.11)	**1.02** (0.95-1.09)	**1.02** (0.95-1.09)
16-20	**0.93** (0.88-0.99) *	**0.88** (0.84-0.93) *	**0.92** (0.87-0.98) *

*- Indicates statistically significant result $p < 0.05$.

Table 9. Crash relative rates for teen (16-20 yrs. old) drivers involved in crashes based on a Poisson's Regression analysis of the 12-county subset of NJCRASH 1997-1999 and 2005-2009.

NJCRASH 1997-1999, 2005-2009 (12-County Subset)						
Age	All Teen Crashes **RR** (95% CI)		Single Vehicle Teen Crashes **RR** (95% CI)		Teen Drivers in Crashes **RR** (95% CI)	
16	**0.69** (0.62-0.76)	*	**0.64** (0.55-0.74)	*	**0.67** (0.60-0.75)	*
17	**0.77** (0.71-0.84)	*	**0.69** (0.63-0.76)	*	**0.77** (0.70-0.83)	*
18	**0.91** (0.86-0.97)	*	**0.84** (0.79-0.89)	*	**0.90** (0.84-0.96)	*
19	**1.09** (1.03-1.16)	*	**1.09** (1.02-1.16)	*	**1.07** (1.00-1.14)	*
20	**1.04** (0.98-1.10)		**1.03** (0.96-1.11)		**1.02** (0.95-1.09)	
16-20	**0.92** (0.87-0.97)	*	**0.87** (0.82-0.91)	*	**0.91** (0.85-0.96)	*

*- Indicates statistically significant result p <0.05.

3.4.4 Fatalities Associated with Teen Drivers in New Jersey

An analysis of the distributions of fatalities by occupant ages is given in Figure 6 for all age groups based on FARS1991-2008 (2008 was the last year available for FARS data) and the distributions of teen related fatalities are given in Figure 6 and Figure 7 based on FARS 1997-2008. These distributions include all fatalities in crashes where there was at least one teen driver, the number of fatal crashes with at least one teen driver, the number of teens killed in traffic accidents, and the number of teens killed in traffic accidents when in a vehicle driven by a teen. These distributions also include pedestrian fatalities in events with teen driver involvement. The percent change for annual teen fatalities, teen fatalities normalized by age-specific census data, teen fatal crashes normalized by age specific census data, and teen involved crash fatalities normalized by the number of adult involved crash fatalities was given for each teen age in Table 10. A Poisson's regression analysis was conducted to determine the relative rates of a fatal crash involving teen drivers and the number of fatalities in teen driver crashes. These relative rates and their respective 95% confidence intervals are given in Table 11. None of these results were shown with statistical significance.

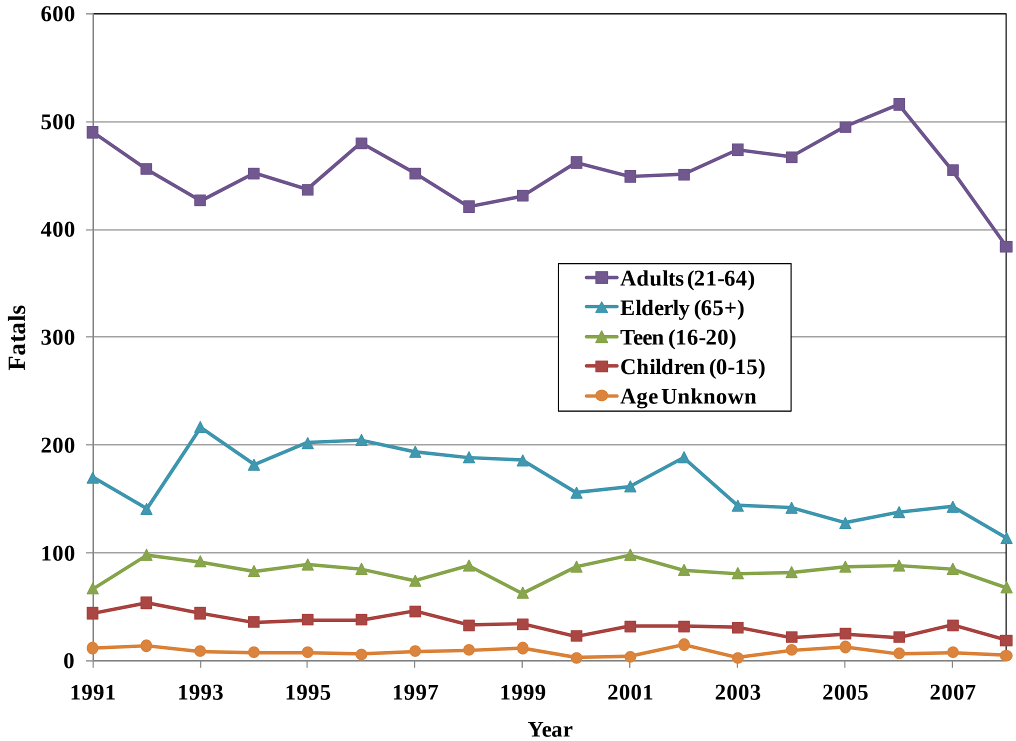

Figure 6. Distribution of New Jersey traffic fatalities by age-range from FARS 1991-2008.

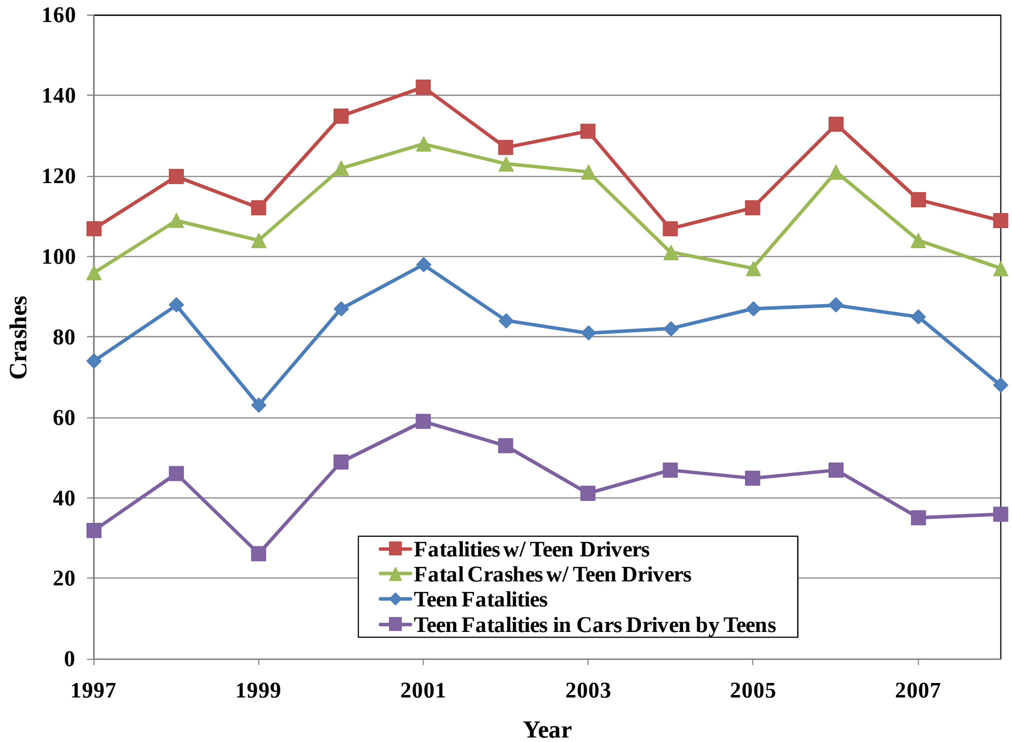

Figure 7. Distribution of fatalities associated with teen drivers from FARS 1997-2008.

Table 10. Reductions in the average annual ratio of teen related fatalities and fatal crashes in New Jersey for pre-GDL and post-GDL driver populations from FARS 1997-1999 and 2005-2008.

FARS 1997-1999, 2005-2008				
		Pre-GDL	Post-GDL	**% Change**
Annual Teen Fatalities		**75.00**	**82.14**	**9%**
	16 yr old Fatalities	8.333	9.000	8.0%
	17 yr old Fatalities	19.667	19.000	-3.4%
	18 yr old Fatalities	21.667	21.000	-3.1%
	19 yr old Fatalities	13.000	17.250	32.7%
	20 yr old Fatalities	12.333	15.750	27.7%
Teen Fatalities / 10,000 Teens		**1.46**	**1.47**	**1%**
	16 yr old Fatalities / 10,000 16 yr olds	0.785	0.646	-6.6%
	17 yr old Fatalities / 10,000 17 yr olds	1.897	1.506	-17.0%
	18 yr old Fatalities / 10,000 18 yr olds	2.166	1.881	-15.9%
	19 yr old Fatalities / 10,000 19 yr olds	1.249	1.804	31.9%
	20 yr old Fatalities / 10,000 20 yr olds	1.242	1.526	18.9%
Teen Driver Fatal Crashes / Adult Driver Fatal Crashes		**0.296**	**0.311**	**4.9%**
	16 Yr Old Fatal Crashes / Adult Fatal Crashes	0.006	0.010	66.9%
	17 Yr Old Fatal Crashes / Adult Fatal Crashes	0.084	0.062	-27.0%

FARS 1997-1999, 2005-2008				
		Pre-GDL	Post-GDL	% Change
	18 Yr Old Fatal Crashes / Adult Fatal Crashes	0.077	0.084	9.7%
	19 Yr Old Fatal Crashes / Adult Fatal Crashes	0.057	0.069	22.2%
	20 Yr Old Fatal Crashes / Adult Fatal Crashes	0.045	0.060	33.9%
Teen Driver Involved Fatalities / Adult Driver Involved Fatalities		**0.295**	**0.319**	**8.1%**
	16 Yr Old Involved Fatalities / Adult Involved Fatalities	0.007	0.013	80.3%
	17 Yr Old Involved Fatalities / Adult Involved Fatalities	0.095	0.076	-19.8%
	18 Yr Old Involved Fatalities / Adult Involved Fatalities	0.087	0.096	9.9%
	19 Yr Old Involved Fatalities / Adult Involved Fatalities	0.061	0.077	25.7%
	20 Yr Old Involved Fatalities / Adult Involved Fatalities	0.050	0.068	35.3%

Table 11. Fatality relative rates for the number of fatal crashes with teen drivers and the number of fatalities in teen driver crashes for pre-GDL and post-GDL driver populations based on a Poisson regression analysis comparing FARS 1997-1999 and 2005-2008.

FARS 1997-1999, 2005-2008		
	Fatal Crashes	**Fatalities in Crashes**
Age	**RR** (95% CI)	**RR** (95% CI)
16	**1.67** (0.69-4.06)	**1.53** (0.64-3.67)
17	**0.74** (0.48-1.13)	**0.68** (0.43-1.06)
18	**0.98** (0.68-1.42)	**1.00** (0.67-1.49)
19	**1.27** (0.81-1.98)	**1.26** (0.79-1.99)
20	**1.29** (0.89-1.88)	**1.29** (0.85-1.95)
16-20	**0.99** (0.76-1.30)	**1.02** (0.78-1.34)

3.4.5 Teen Crashes and Teen Fatalities by County

To determine the statewide distribution of teen crashes in the post-GDL time period, teen crash metrics were computed for each county based on NJCRASH 2005-2009. This range of crash years would only include teen drivers who were licensed under the GDL regulations. The cumulative distribution of the average annual populations by county is given in Figure 8. The five counties with the largest number of annual teen driver crashes are given in Figure 9. Similarly, Figure 10 normalizes the number of teen crashes by county to the number of adult crashes to note the five counties with the highest normalized teen crash rates. The five counties with the most fatal crashes involving teen drivers are given in Figure 11. Figure 12 ranks the counties by teen fatality counts from 2005-2008 and Figure 13 normalizes these counts to the number of adult fatalities by county to reveal the five counties with the highest normalized rate of teen fatalities.

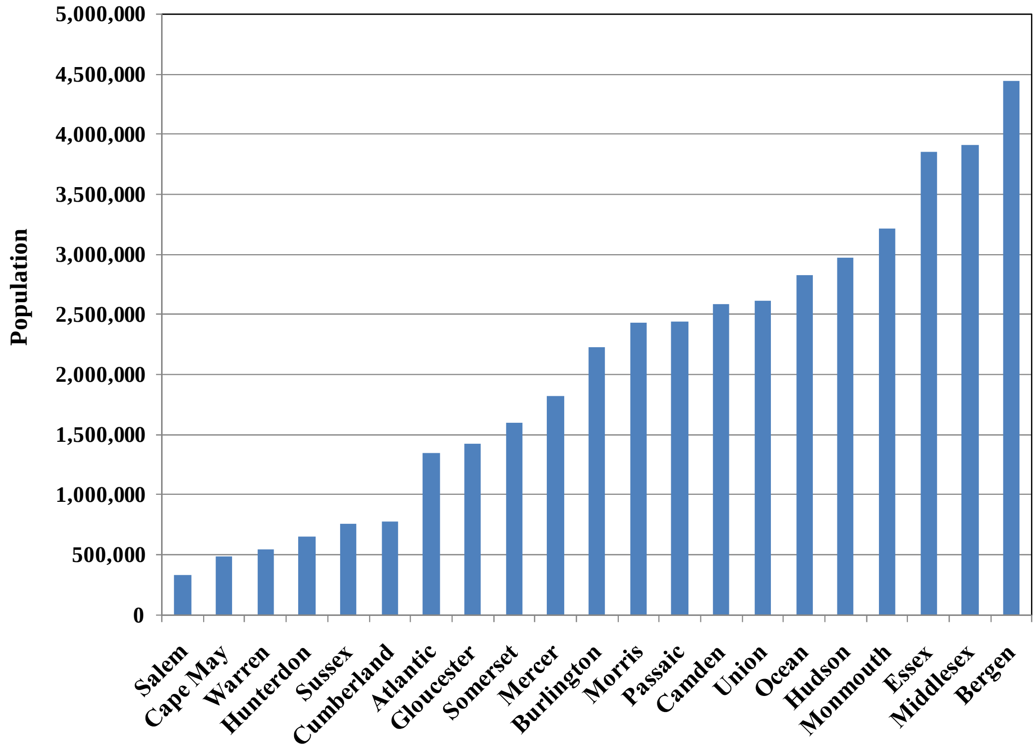

Figure 8. The average annual New Jersey Population from 2005-2009 by county (USCB, 2010).

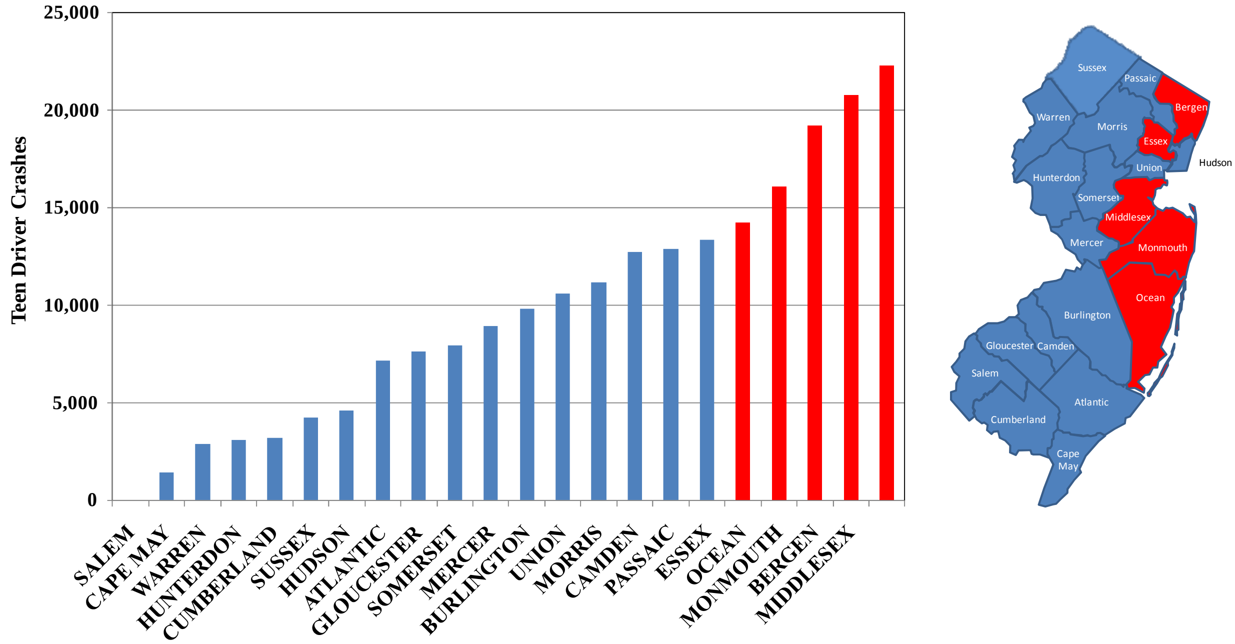

Figure 9. Cumulative frequency distribution of all teen driver crashes by county from NJCRASH 2005-2009.

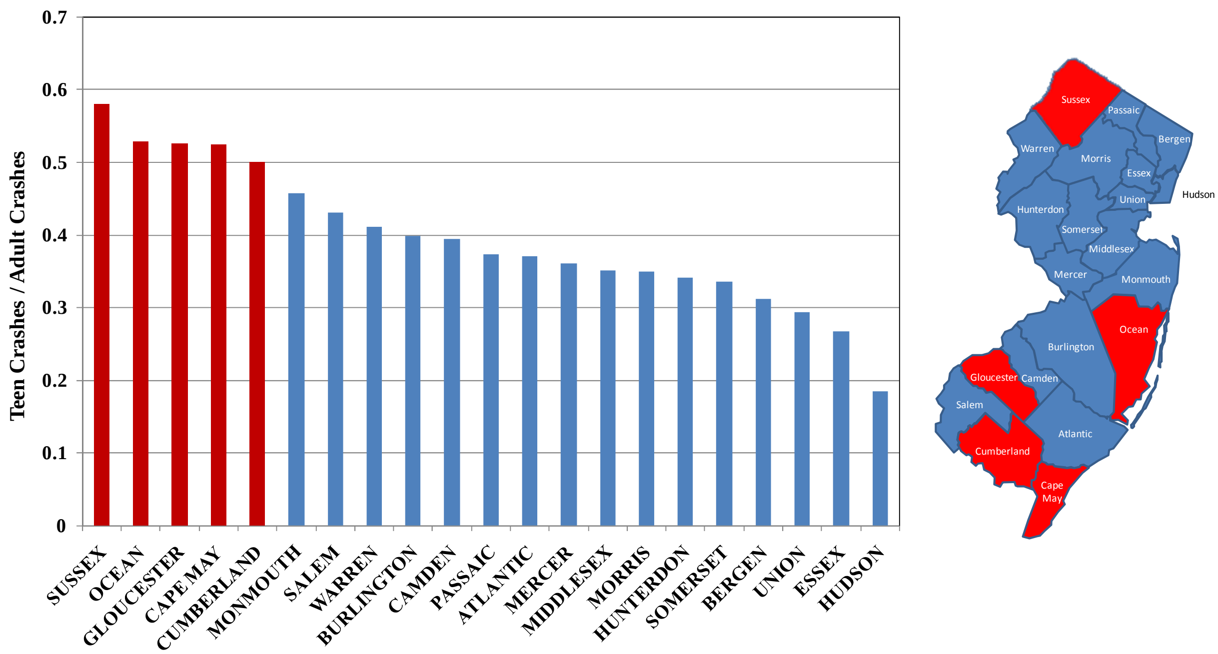

Figure 10. Ratio of teen driver (16-20 yrs. old) crashes to adult (35-55 yrs. Old) crashes by county from NJCRASH 2005-2009.

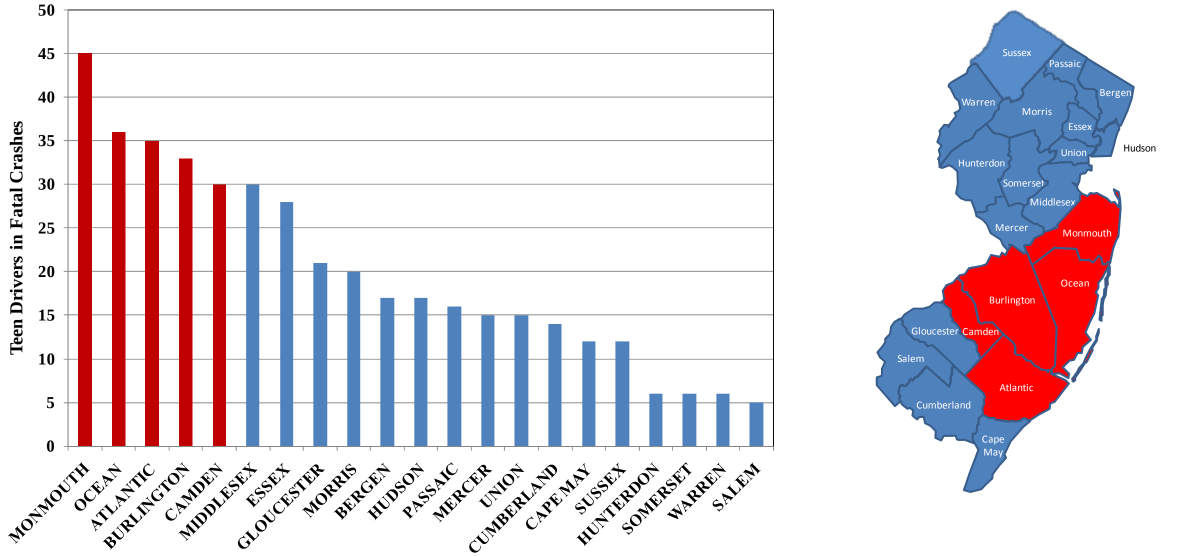

Figure 11. Distribution of fatal crashes involving teen drivers by county from FARS 2005-2008.

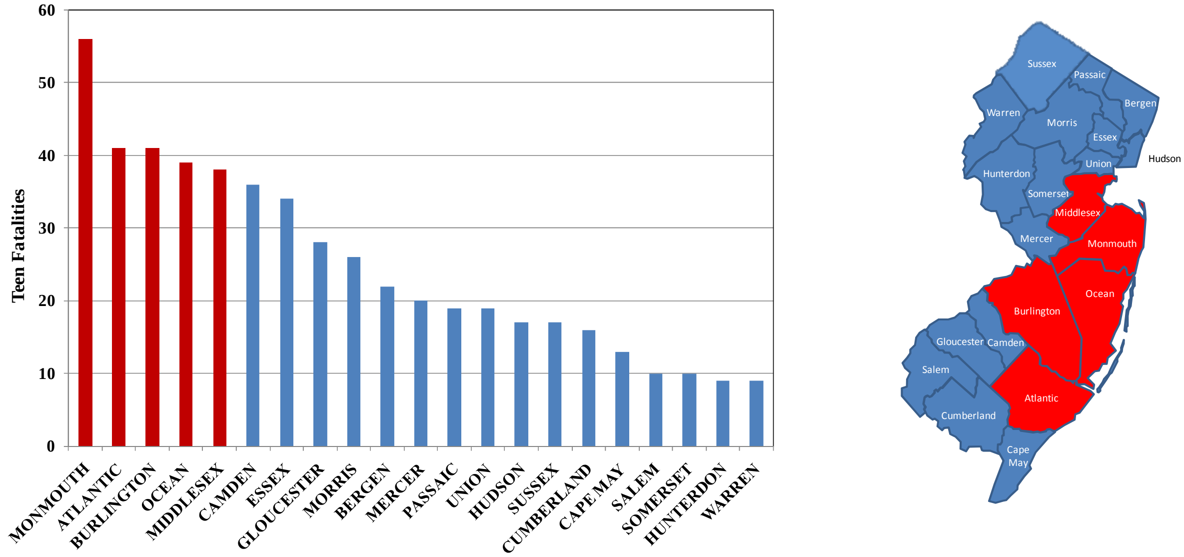

Figure 12. Distribution of teen fatalities by county from FARS 2005-2008.

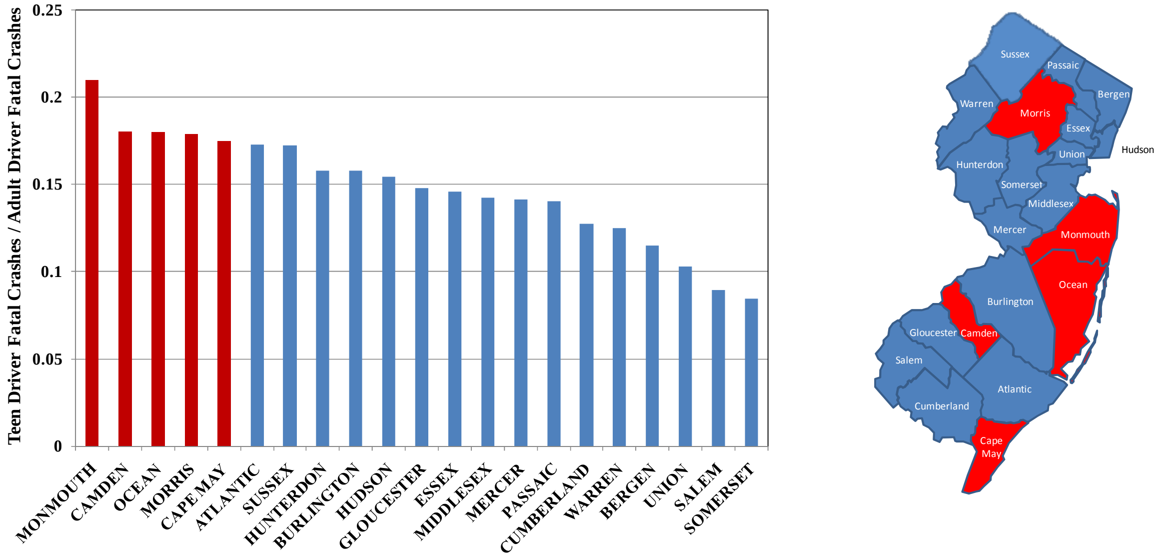

Figure 13. Ratio of teen driver fatal crashes (16-20 yrs. old) to adult driver (35-55 yrs. old) fatal crashes by county from FARS 2005-2008.

3.5 Discussion

3.5.1 Crash Rate Analysis

First, it is necessary to again acknowledge the inconsistencies in the NJCRASH dataset. The distribution of crashes by age group shown in Figure 4 express some of the problems associated with the format change over that occurred in 2001. Prior to 2001, the crash distribution was less consistent, year to year, than the crash distributions seen for the 2001-2009 format. Steps were taken prior to these analyses that included removing all duplicate crash records and assigning accurate driver ages to the NJCRASH 1997-2000 format. These steps are outlined in Appendix A. From a qualitative analysis, it appears that the resulting corrected dataset exhibited the same inconsistencies in annual crash counts for both teens and adults. Therefore, it was assumed that the errors in the data are evenly distributed amongst all ages and thus were canceled out after normalizing the crash rates of teens by those of adults. Nonetheless, the effects of the formatting changes as well as the inconsistencies in the older format may still play a role in the results and discussion.

Figure 5 shows that the number of crashes by age for teenage drivers was relatively consistent with time. However, if it is assumed that the number of licensed drivers for each age group grows annually, this would suggest a decrease in crashes per licensed driver. Unfortunately, licensure data was not available and population estimates were used as a surrogate. Figure 5 shows that 16 year old drivers have the fewest crashes of any age group. At this age, the driver is under the supervision of a fully licensed driver. The number of annual crashes for teens decreases with age for 17-20 year old drivers. This would suggest that the more experienced teen drivers are indeed better at avoiding crashes.

The rate of teen crashes and the rate of teen drivers involved in crashes were shown to have decreased with the implementation of GDL in New Jersey. Table 5 shows a decrease in the ratio of teen/adult involved crashes, teen/adult drivers in crashes, and teen/adult drivers involved in single vehicle crashes corresponding with the implementation of GDL. From Table 5, the ratio of teens vs. adults involved crashes in all counties decreased by 6.6% when normalized by their respective age-specific census counts and the ratio of teen vs. adult drivers in crashes decreased by 8.3% when normalized by their respective age-specific census counts. The ratio of teen single vehicle crashes vs. adult single vehicle crashes decreased by 11.9% with the implementation of GDL when normalized by their respective age-specific census counts. Based on the Poisson's regression results shown in Table 8 and Table 9, the teen driver crash rates for 16-18 year olds significantly decreased when adjusted for population and adult crash rates. However, 19-20 year old drivers, who were graduates of the GDL system, showed increases in their crash rates, although not with statistical significance in most comparisons.

In general, greater effectiveness was shown from the Top 12 counties analysis. With this approach, the ratio of teens vs. adults involved crashes decreased by 7.9% when normalized by their respective age-specific census counts and the ratio of teen vs. adult drivers in crashes decreased by 9.4% when normalized by their respective age-specific census counts. The ratio of single vehicle teen crashes vs. single vehicle adult crashes decreased by 13.4% with the implementation of GDL when normalized by their respective age-specific census counts. The differences seen for the analyses that included all counties as compared to the Top 12 county subset may be the result of various factors. First, these may simply be county specific changes in teen crash rates. However, because the Top 12 counties were ranked based on data consistency and accuracy, the differences may also be the result of better data quality.

For all analyses, case years 2000-2004 were excluded to minimize any changes associated with teen licensing. However, the 2001 case year normalized by the census data had the highest ratio of teen vs. adult driver involved crashes and teen vs. adult drivers for the post-GDL period. In this year, there would be the smallest number of teens who had been licensed under the GDL program in the GDL era. For the subsequent years, the ratios generally decreased until 2005, when all drivers between the ages of 16-20 would have been licensed under the GDL program.

For case years 2006-2009, the ratios of teen/adult crashes and teen/adult drivers in crashes are relatively constant. This reinforces the notion that the changes seen between the pre-GDL and GDL licensed populations may in fact be heavily reliant on GDL regulation effectiveness.

3.5.2 Comparing the New Jersey Model to the U.S.

Other studies, both domestically and abroad, have shown similar successes associated with GDL regulations. However, because of New Jersey's strict licensing regulations, it was not completely appropriate to directly compare the crash rates of a particular age group against the same age group from another state. Instead, this section compares the New Jersey effectiveness results to those reported for teens of an age corresponding to a similar licensing stage in another state. The reported effectiveness for other GDL programs in the United States are given in Table 12.

Table 12. Reported crash rate effectiveness measures from other GDL programs in the United States

State	Author	Teen Population	Adult Population	Pre-GDL	GDL	% Difference
Michigan	Shope et al, 2001	16*	25+*	2.170	1.630	-24.9%
Maryland	Kirley et al, 2008	16	30-59	-	-	-18.0%
California	Rice et al, 2004	16	25-34	-	-	-23.0%
		17	25-34	-	-	-6.0%
California	Zwicker et al, 2006	16	24-55	-	-	-23.0%
North Carolina	Foss, 2001	16	25-54	-	-	-27.0%
Florida	Ulmer et al, 2000	15*	25-54*	0.140	0.110	-21.4%
		16*	25-54*	1.230	1.090	-11.4%
		17*	25-54*	1.630	1.530	-6.1%
		18*	25-54*	1.870	1.870	0.0%
Connecticut	Ulmer et al, 2001	16*	25-54*	1.280	1.000	-21.9%
		17*	25-54*	1.620	1.710	5.6%
		18*	25-54*	1.820	1.990	9.3%
Kentucky	Agent,2001	16-19	20+	0.168	0.160	-4.8%
New Jersey	Thor, 2010	16-20*	35-55*	0.362	0.344	-5.0%
		16*	35-55*	0.034	0.026	-24.8%
		17*	35-55*	0.54	0.476	-11.8%
		18*	35-55*	0.458	0.445	-2.7%
		19*	35-55*	0.391	0.389	-0.3%
		20*	35-55*	0.347	0.346	-0.3%
New Jersey: 12-County	Thor, 2010	16-20*	35-55*	1.837	1.683	-8.4%
		16*	35-55*	0.022	0.017	-23.5%
		17*	35-55*	0.362	0.315	-12.9%
		18*	35-55*	0.296	0.296	-0.1%
		19*	35-55*	0.25	0.259	3.3%
		20*	35-55*	0.22	0.227	3.1%

*Normalized by Population

A study by Rice et al (2004) investigated the crash rates of 16 (minimum age for a provisional license) and reported a 23% and 20% reduction in 16 year old crash rates in California when normalized by the crash rates of 25-34 year olds in 2000 and 2001 (GDL era), when compared to the same crash ratio in 1997 (pre-GDL). In a similar study Foss et al (2001) computed a crash ratio for 16 year old (minimum age for a provisional license) drivers normalized to the crash rates of 25-54 year olds in North Carolina. The crash ratios of two years pre-GDL (1996 and 1997) were compared to the crash ratios of one year in the GDL era (1999). The crash ratio in 1999 was 23% lower compared to the ratio in 1996 and 28% lower when compared to 1997. Fohr et al (2005) showed a 13.8% reduction in 16 year old crashes post-GDL when normalized by 25-59 year old drivers in Wisconsin. Interestingly, Kirley et al (2008) found a statistically significant 18% (CI: 29%-4%) reduction in crash rates for 16 year old drivers when normalized to population but a statistically insignificant 9% (CI:-7%-27%) increase in crash rate when normalized to the number of licensed drivers in Maryland. An appropriate comparison population from the New Jersey population would be 17 year old drivers because this is the minimum age for restricted but unsupervised driving. Our study showed 18.8% reduction in 17 year old driver involved crashes from all counties and a 19.8% reduction in the 12-county analysis. Both of these are in the same range as what was seen from other state GDL programs.

The same study by Rice et al (2004) also investigated the crash rates 17 year olds (minimum age for GDL graduation). However, only a 6% and 3% reduction was seen for 17 year olds in these same years. Similarly, Fohr et al (2005) only showed a 6.2% reduction in 17 year old crashes in the GDL era when normalized by 25-59 year old drivers in Wisconsin. Our study showed an

8.2% reduction in the rate of 18 year old driver involved crashes in all counties and a 5.3% reduction from the 12-county analysis. Again, the New Jersey GDL program appears to possess an effectiveness which is in line with other, similar studies.

Each of the referenced studies employed different statistical approaches to present their results, making it difficult to directly compare with the results of the New Jersey experience. For example, the results presented in the literature often compared only one year pre-GDL vs. one year in the GDL era. The effectiveness values presented in our study were averaged over a much larger range of crash years both before and after GDL implementation. Despite, the differences in GDL regulations and effectiveness calculation methodologies, the computed GDL effectiveness metrics for New Jersey appear to reflect the conclusions of similar studies with regard to teens that were licensed under the regulations of GDL programs nationwide.

Our study also includes older teens (18-20 years old); these ages were not included in other studies. This provides a unique perspective. It was found that while 18 year old crashes decreased in a similar manner as other reported by other studies that analyzed the crash rates of teen drivers in their first year after GDL implementation. However, the crash rates of 19-20 year old drivers increased significantly. This suggests that teen drivers in New Jersey who have graduated from the GDL program are actually more likely to be in a crash when compared to their pre-GDL peers.

3.5.3 Teen Fatal Crash Analysis

The annual fatality counts in traffic crashes in New Jersey were relatively constant from 1991-2008, as shown in Figure 6. However, over the 1997-2008 time period, there was a slight increase in annual teen fatalities, teen fatality rate normalized by population, teen fatal crashes, and traffic fatalities resulting from accidents involving a teen driver. This was contrary to some studies, particularly studies from abroad, that have shown reductions in the number of teen driver related traffic fatalities (Bouchard, 2000; Foss et al., 2001; Kingham et al., 2008). However, similar to the New Jersey experience, several U.S. studies have shown increases in teen fatality rates for certain groups. More specifically, it has been found that the fatality rates amongst teens are often age dependent. For example, Males (2007) noted an increase in the overall fatality rates for teen drivers under GDL regulation in California as well as increases in teen driver fatality rates for 18 year olds, yet a decrease in fatality rates for 16 year old drivers. Agent (2001) also found an overall increase in teen driver fatality rates from pre-GDL period to the GDL period. However, Agent found that the fatality rates of teen drivers decreased for 16 and 18 year olds, but increased for 17 and 19 year olds.

Our FARS analysis found that the annual fatality counts for 16-18 year olds decreased after GDL implementation, but the annual fatality counts of 19 and 20 year olds increased over the same time period. Furthermore, the rate of fatal crashes for 18 year old drivers increased along with 19-20 year old drivers when normalized by adult driver fatality rates. Similar to findings of the crash rate analysis, it is possible that regulations associated with the New Jersey GDL laws are most effective while the drivers are subject to the extra regulations, yet are less effective after the drivers have become fully licensed and are no longer under GDL regulation, thus explaining these age-dependent trends. A Poisson's regression analysis did not show a significant difference in the fatality rates for any age after GDL implementation when compared to the pre-GDL populations. However this may be at least partially a result of the relatively small number of annual teen fatalities. What is most troubling is that the crash and fatality rates are higher for 19-20 year old GDL graduates when compared to 19-20 year old drivers who were licensed before GDL in New Jersey. It is possible that, through regulation, GDL limits the exposure of teen drivers to many driving experiences. Yet, after graduation from the GDL program they actually possess less experience, resulting in higher crash and fatality risks.

3.5.4 Williams et al (2010) Comparison

A study performed by Williams et al (2010) investigated the effectiveness of the New Jersey GDL program as well. However, their methodology varied from our study in some significant ways. First, fewer crash years were included in their analysis with 1998-2000 defined as the pre-GDL period and 2002-2005 as the GDL period. Furthermore, the study compared the crash and fatality rates for drivers aged 16-24 years old. This becomes a methodological issue because some drivers included in the time period defined as the GDL era were not licensed under the GDL system. Also, our study showed that normalized crash rates did not appear to reach a constant rate for all teen drivers (16-20 years old) until 2005, the last year of data included in the Williams study. We speculated that the crash rates did not plateau until 2005 because GDL did indeed have an effect on the crash rates of teen drivers and it was not until 2005 that all 16-20 year old drivers would have been licensed under the New Jersey GDL system. However, Williams et al did specify that their reasoning for limiting the dataset in this way was to eliminate some of the known errors in the dataset, particularly from 1997-2001. However, rather than eliminating these crashes, our study chose to perform a parallel analysis on a 12-county subset whose data was compared directly to outside sources for data quality verification. This allowed us to include five more years of crash data, and presumably a cleaner data source. Nonetheless, the results published by Williams et al showed similar GDL effectiveness calculations when compared to our study. It was reported that there was a 16% reduction in crash rate for 17 year old drivers and a 10% reduction in crash rate for 18 year old drivers. This compares to our 18.8% reduction in 17 year old driver crashes and 8.2% reduction in 18 year old driver crashes. Also, Williams et al stated that crash rates of 19 and 20-24 year old drivers were not significantly different from pre-GDL to GDL time periods. However, this would be expected because many of the drivers in these age groups would have been licensed prior to GDL implementation. In contrast, our study only looked at 19-20 year old drivers who were licensed after GDL implementation and found that the crash rates actually increased when compared to pre-GDL drivers of the same age.

Regarding teen driver fatal crashes, Williams et al utilized a larger range of years (pre-GDL:1995-2000, GDL era: 2002-2007). From this analysis they reported a 25% and 4% reduction in fatalities in crashes involving 17 and 18 year old drivers, respectively, after GDL implementation. Our study found a similar reduction in fatal crashes for 17 year olds at 27%, however, our study found an increase of 9.7% in the rate of fatal crashes for 18 year old drivers. However, variations between the two studies are most likely the result of the small number of fatalities per year for teen drivers in New Jersey. This is also shown in the large confidence intervals resulting from the Poisson's regression model built around fatality data for our study. Therefore, it would be prudent to assess the results regarding fatality rates from both studies with caution.

3.5.5 The STANDUP Act

The STANDUP Act was presented as a way to encourage states to update and improve their licensing procedures. This was at least partially based on the assumption that by increasing the minimum ages for each stage of licensure (as is currently in place in New Jersey) that there would be a decrease in the crash and fatality rates for teen drivers nationwide. The results from this study have shown that the changes in crash and fatality rates for teen drivers in New Jersey are comparable to the rates seen in other states for teens in the same stage of licensure. However, an extension of the minimum age requirements would reduce the number of total crashes and fatalities for teens in age groups that are under GDL regulation. Regardless, it has been found that the crash rates and fatality rates will return to their pre-GDL levels after graduation from GDL, or possibly increase. Therefore, it is difficult to claim that the STANDUP Act would actually improve the driving ability of teen drivers or reduce teen driver crash risk for a given stage of licensure. Instead, it appears that extending the minimum age for each stage of licensure only shifts the age at which the same effectiveness is seen. However, it may be fair to assume that the overall number of teen driver crashes and fatalities would decrease for drivers under the regulation of GDL because the exposure at each age would be reduced.

3.5.6 County Analysis

New Jersey is the most densely populated state in the United States, yet it is comprised of a wide range of rural and urban landscapes. As such, the distribution of crashes across the 21 counties can vary greatly. As shown in Figure 9, 53% of all teen crashes from 2005-2009 in New Jersey occurred in five counties: Essex, Ocean, Monmouth, Bergen, and Middlesex. For these analyses, the 2005-2009 crash period was chosen to determine the counties where teen driver issues are most prevalent after GDL implementation. The large teen driver crash counts in these five counties are most likely due to larger populations. However, it is interesting to note how teen crashes rates normalized to adult crash rates within individual counties vary, regardless of population. The five counties with the highest ratio of teen crashes vs. adult crashes included four counties with relatively low populations (Sussex, Gloucester, Cumberland, and Cape May counties) and only one with a relatively high population (Ocean county). This suggests that the remaining issues may be more prevalent in low population areas. It is not surprising that Monmouth, Ocean, and Middlesex counties were among the counties with the highest teen fatality counts over this time period, as shown in Figure 12, because they are among the counties with the highest total crash rates. However, Atlantic and Burlington are not among the counties with the highest crash rates, but are in the top five for teen fatalities. Finally, Figure 13 shows that the ratio of teen fatalities to adult fatalities by county is distributed across counties with varying populations and crash frequencies as well as location within the state. This again indicates that the remaining issues associated with teen drivers are state-wide. However, it is worth noting Monmouth County was in the top five for each comparison regarding crash counts and fatalities by county except the ratio of teen and adult crashes, in which it is ranked sixth.

However, identifying the particulars with regard to why this county would have more issues associated with teen drivers would necessitate a further review.

3.5.7 Limitations

With regard to crash rate, it appears as though the GDL has succeeded in reducing crash risk for teen drivers who are under the regulations of GDL in New Jersey. However, the limitations of this research must be acknowledged. First, the 1997-2000 NJCRASH format has data quality problems. However, if we assume that these errors are evenly distributed across both the teen and adult driving populations, and as a result are cancelled out through the use of age group normalization. Also, as an alternate approach for adjusting for the 1997-2000 data quality problems, we computed effectiveness with a 12-county subset of data which we judged to be of higher quality than the overall dataset. If we assume that GDL effectiveness is relatively consistent across the state, then the 12-county subset should give us a reasonable estimate of statewide GDL effectiveness.

The exposure metric used in these analyses are age range-specific New Jersey census counts. The assumption for using this data as an exposure metric would be that the census counts are at least proportional to the number of drivers for each age range. Therefore, if the proportion of licensed teens per population and the number of licensed adults per population remain relatively constant, then all reported results would decrease by a constant scaling factor for each year relative to the number of licensed drivers. However, this assumption may not be completely accurate. First, it was shown that the ratio of teens vs. adults was not constant from 1997-2009. Also, with the new regulations associated with the GDL program, it is very probable that the proportion of licensed teens has changed from the pre-GDL period to the GDL period. Nonetheless, reliable licensing data was not available for New Jersey drivers, and as such, the census data served as the best available normalizing exposure metric.

Finally, an induced exposure approach was utilized to account for changes in the driving environment for all drivers that are unrelated to GDL implementation. An underlying assumption of this approach is that the ratio of exposure, e.g. vehicle miles traveled, for teen and adult drivers would have remained constant with time. However, it is possible that the travel exposure of teen drivers decreased after GDL implementation as a direct result of the restrictions that were instituted as part of the program. Unfortunately, age-specific VMT was not available for New Jersey drivers so a check of this assumption was not possible.

3.6 Conclusion

This study compared teen crashes from the pre-GDL period (1997-1999) to teen crashes of the GDL era (2005-2009). Crashes in 2000-2004 were not included in this study because this was considered a transition period for GDL implementation. The subsequent results showed reductions in the crash and fatality rates associated with teen drivers who are under GDL regulation. However, it was found that the crash and fatality rates of teen drivers who have graduated from GDL in New Jersey are frequently higher than their pre-GDL peers. Overall, the GDL effectiveness in New Jersey appears to agree with the results of similar regulations in other states and countries for drivers in the same licensing stage. As a result, it appears that the unique effectiveness of New Jersey GDL regulations is that the reductions in crash and fatality rates are shifted by a year compared to most other GDL programs in the United States. As such, based on the New Jersey experience, it can be assumed that the STANDUP Act would only serve to postpone teen crashes by further reducing exposure through higher minimum age requirements.

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4. The Effectiveness of New Jersey’s Graduated Driver’s License Regulations on Teen Driver Violation Rates

4.1 Introduction

Many states have reported reductions in the crash rates for teen drivers after GDL implementation. Monitoring crash rates, however, does not evaluate how teen driver behavior in risky, but non-crash, events may have changed as a result of GDL implementation. It is unclear whether or not the behaviors of teen drivers have changed after GDL implementation. One method for comparing teen driver behaviors before and after GDL implementation is to investigate the type and frequency of violations for teen drivers in both the pre-GDL period and after GDL implementation. If GDL has improved the driving behavior of teens, we would hope to see a reduction in the number of traffic violations and a change in the type of traffic violations.

4.1.1 Graduated Driver’s Licensing

Graduated driving licensing laws have been implemented in all 50 U.S. states and the District of Columbia (IIHS, 2010). GDL licensing regulations allow for the gradual accumulation of driving experience for teen drivers through practice in lower risk driving scenarios. These programs often require a period of supervised driving, restrictions on the number of passengers, restrictions on the hours of operation, or any combination of these and other regulations. In 1996, Florida became the first state to implement a modern GDL system in the U.S. (Doherty, 1997; Ulmer, 2000). All other states have updated their licensing laws since this time to include at least some features of a GDL program. However, significant differences exist between each state’s licensing laws.

The New Jersey GDL program is considered to be one of the most progressive and stringent in the United States (Williams et al., 2010). It is comprised of three stages of licensure for new teen drivers: learner's permit at a minimum of 16 years of age; provisional license at 17 years old; and a basic license at 18 years old. Each phase carries restrictions which reduce novice driver exposure to risky situations, such as driving at night. In New Jersey, the learner's permit requires a minimum of six months of supervised driving. The provisional license allows unsupervised driving for one year, but carries several restrictions including a ban on driving between 11pm and 5am, and limits on the number of passengers. At each stage, these restrictions are gradually lifted if the driver is violation-free until full driving privileges are reached. Our analysis of the New Jersey GDL system has shown that after GDL implementation, the crash rate for 16 year old drivers has decreased by 30% and the crash rate for 17 year old drivers has decreased by 19%. This is similar to the 20-30% reduction from shown in other published reports concerning GDL programs in the United States (Shope and Molnar, 2003; Simpson, 2003; Williams, 2006).

4.1.2 Violation Analysis

While the literature on crash and fatality rates for teen drivers following GDL is large, analyses of violation rates for teen drivers are limited. Nonetheless, a few studies have shown reductions in the number of teen driver violations or convictions after the implementation of GDL within a given state. Raymond et al (2007) reported a reduction in the teen driver conviction rate after the implementation of GDL in Oregon. However, these rates were not compared to a non-GDL population (e.g. adult drivers) to see if this trend was teen-specific or simply a reflection of a statewide trend. On the other hand, the rate of license suspensions for teen drivers were normalized to the rate of suspension for adult drivers and it was found that teen drivers had a lower suspension rate after GDL implementation. Also, 18- and 19-year old novice drivers had higher conviction and suspension rates compared to 16- and 17- year old novice drivers. It was stated that this is most likely a reflection of differences in exposure rather than a result of differences in driver behavior or ability. This is because, in Oregon, teens that are licensed after turning 18 are not subject to the requirements of GDL. Furthermore, GDL restrictions are lifted for all drivers when they turn 18, regardless of their progress in the GDL program. Interestingly, teens that were licensed at 18- or 19-year old (i.e. no GDL regulation) were shown to have lower convictions rates after GDL implementation when compared to the same population pre-GDL. This indicates that while conviction rates may have decreased for 16- and 17-year olds, this result is not entirely an effect of GDL because the rates decreased for non-GDL drivers as well.

A study performed by Falb (2005) reported a 47-56% decline in the number of 16-year old driver violations in the 3-6 years after GDL implementation in Iowa. 16 years old is the minimum age for a provisional license in Iowa. This study only compared the violation rates to those of the last year before GDL implementation and did not specify if the number 16-year old licensed drivers declined as well. However, such a dramatic decrease reveals a promising result following GDL implementation.

Other reports have touched upon the types of violations that teens receive. For example, a study found that the citation risk for teen drivers is highest in their first few months of licensure

(McCartt et al., 2003). Furthermore, a study performed prior to GDL implementation in the United States reported that teen drivers, when involved in multiple vehicle crashes, were more likely to be cited for errors when compared to adult drivers (Williams et al., 1995). To date, however, little is published on how GDL implementation has influenced the traffic violation rate of teen drivers.

In the New Jersey GDL program, penalties are triggered when violation points are accumulated by a teen driver. In the event that a teen driver is convicted of a violation that carries two points, a warning letter is sent to the driver to instruct them that if they are convicted of another point carrying violation while a GDL driver, they will be subject to further penalty. Following the accumulation of three or more points while holding a GDL license, the driver is required to participate in a four hour probationary driver program (PDP) safe driving course. After the completion of this course, the GDL driver is given a credit of three violation points on their record, but subjected to a 12-month probationary period. During this time, if the driver is convicted of another point carrying violation, their license will be suspended. For non-GDL drivers, license suspensions most often occur after the accumulation of more than 12 violation points. However, point credits can be awarded if the driver is violation-free for a year or completes a driver improvement program.

Objective: Determine the influence of New Jersey GDL implementation on traffic violation rates of teen drivers in New Jersey.

4.2 Methods

The New Jersey Motor Vehicle Commission (MVC) maintains a dataset that is a census of all recorded events in their driver monitoring system. Events in the system included warning notices for point accumulations, suspension scheduling, traffic violations, and crashes for each driver licensed in the state. Also included in the dataset was basic driver record information, e.g. date of birth and gender, followed by details corresponding to each event, e.g. event type, event date, points assessed. The details of up to 100 events per driver record were provided. The dataset only included records for drivers with events. Drivers with clean driving histories were not included in this dataset. In all, the dataset contained the records of 9,591,584 drivers and 110,569,589 events.

4.2.1 Data Analysis

Our analysis of teen violations sought to identify trends in the violations received by teen drivers, both in number and type, as well as directly compare the pre-GDL and GDL licensed teen driver populations. This allowed us to identify the changes in teen driver violations in New Jersey that corresponded to changes in the licensing procedures.

For our study, teen drivers were defined as 16-20 year olds. Teen driver violation rates and types were compared to those of adult drivers, defined as 35-55 year olds. This method provided a comparison population (adult drivers) consisting of an age range where the drivers were not subject to the GDL regulations, but were assumed to have been exposed to the same driving environment. Relative rates were computed that compared the violation rates of pre-GDL and GDL teen drivers. A relative rate greater than one indicates the teen drivers had a higher violation rate in the GDL era (after GDL implementation) as compared to the pre-GDL era, while accounting for overall violation distribution trends (i.e. the adult violation rate).

In each effectiveness calculation, case years 2000-2004 were excluded. This accounts for two factors. First, this limits the influence that the GDL implementation may have had on teen licensing trends. This includes variations in teen licensing just prior to and just following GDL implementation. Uncharacteristic swings in licensing may be the result of teens trying to avoid the new, stricter regulations by licensing before the changes were instituted (Ulmer, 1999; Foss et al., 2001; Rice et al., 2004). Secondly, by defining the post-GDL period as 2005-2008, we ensured that only teen drivers who were licensed under the GDL regulation were included. The removal of the 2000-2004 case years produced two distinct populations of teen drivers: 1) 16-20 years olds licensed prior to GDL regulation (pre-GDL) and 2) 16-20 year olds licensed under GDL regulation (GDL era). All subsequent effectiveness metrics directly compare the teen driver violations of both of these populations.

The violation counts for 2008 were only included if they occurred before September 17. This is the date that a plea-agreement ban was instituted in New Jersey for all GDL drivers (Milgram, 2008). This ban prohibits GDL drivers from pleading a point-carrying violation to a non-point carrying violation. It was found that teen drivers had been avoiding penalties built in to the GDL program that were meant to punish GDL drivers who were cited for point carrying violations. The count of teen driver violations that occurred after September 17, 2008 likely has a ratio of point-carrying violations to non-point carrying violations that would not be comparable to the prior years. However, to account for the missing dates, the count of violations prior to September 17, 2008 was scaled to create a count representative of an entire year. The violation counts were multiplied by 366/261; the inverse ratio of the number of days prior to this date in 2008 (2008 was a leap year).

For the violations data, a Poisson's distribution was assumed for the violations counts and a regression equation was applied to compute 95% confidence intervals for all relative rates. Driver age (teen vs. adult), GDL time period (pre-GDL vs. GDL-era), and an interaction predictor for these two variables were included in the regression model. Furthermore, age-specific population counts, obtained from the U.S. Census Bureau, were included as an offset in the regression model (USCB, 2010). The complete regression model is shown in Equation 5. Relative rates were computed through the exponentiation the regression coefficient for the teen driver-GDL interaction. The relative rates express the ratio given in Equation 6.

$$log\left(\frac{Violations}{Population}\right) = \beta_0 + Driver\ Age\left(x_{age}\right) + GDL\ Period\left(x_{GDL}\right) + Age/GDL\left(x_{age/GDL}\right)$$ **Equation 7**

$$Relative\ Rate = \frac{\left(\frac{Teen\ Violations}{Population}\right)_{GDL-Era}}{\left(\frac{Teen\ Violations}{Population}\right)_{Pre-GDL}}$$ **Equation 8**

To properly compute the confidence intervals, a negative binomial distribution was assumed to compute the variance within the violation populations and to account for overdispersion within the data distribution. Overdispersion occurs when the variation about a fitted value is greater than what is consistent with the Poisson distribution (i.e. the variance of the fitted variable is not equal to the mean). The negative binomial compensates for the level of overdispersion within the model and computes the variance accordingly (Berk and McDonald, 2007). The SAS v9.2 software was used for all database analyses and statistical computations.

The analyses were conducted on all teen driver violations, zero-point carrying violations, all point-carrying violations, and “estimated” point carrying violations. To determine the number of estimated point-carrying violations, the number of “Unsafe Operator”, “Obstructing Passage of another Vehicle”, and “Delaying Traffic” violations were combined with the total count of point-carrying violations in each year. It had previously been shown that these violations were most commonly assessed when a point-carrying violation was pleaded to a zero-point carrying violation (Carnegie et al., 2009). However, the Carnegie study was conducted for violations given after 2004 and therefore did not account for “Failure to Obey Directional Signals” violations. These were the most common violation given in plea-agreements before the introduction of “Unsafe Operator”. As a result, the “Failure to Obey Directional Signals” violations were included in the estimated point-carrying violations counts as well. Including these pleaded violations with the number of point-carrying violations was intended to account for all violations that were originally assessed as point-carrying. The hypothesis was that by accounting for both violations that carried points and those that were originally given because of point-carrying violation behaviors, this would provide a more complete perspective on teen driver behavior.

Table 13 gives examples of violations that carry varying levels of points. The violations of all teens were aggregated to show an overall picture of the effect of GDL regulation on teen driver violations as well as separate analyses for each age. Unfortunately, the licensing status of the teen drivers was not available in the dataset so it was not possible to conduct an analyses based on license status.

Table 13. Example violations by point value.

Zero-Point Violation	• Failure to Wear a Seat Belt • Cell Phone Use While Driving • Unsafe Operation of a Motor Vehicle
Point-Carrying Violation (0-3 pts)	• Speeding (in excess of speed limit 1-14 mph) • Failure to Observe Traffic Signals • Careless Driving
Point-Carrying Violation (4+ pts)	• Racing • Reckless Driving • Speeding (in excess of speed limit 15+ mph)

4.3 Results

The number of drivers with violations, the number of total violations, the number of suspensions, and the census estimates for the pre-GDL and GDL era are given by age and year in Table 14.

Table 14. Annual distributions of drivers with violations, the number of total violations, the number of suspensions, and the census estimates for the pre-GDL and GDL era (MVC, 1997-1999 vs. 2005-2008).

	Age	1997	1998	1999	2005	2006	2007	2008
Drivers with Violations	16	587	656	655	572	533	565	438
	17	14,722	15,825	16,062	13,823	13,855	15,602	17,170
	18	16,985	17,862	18,254	16,691	17,687	21,272	23,614
	19	16,706	17,574	17,940	17,406	17,716	21,740	25,157
	20	15,801	16,543	16,914	16,237	17,328	20,454	24,197
	16-20	64,801	68,460	69,825	64,729	67,119	79,633	90,576
	35-55	167,353	177,719	182,417	166,023	177,686	211,159	248,168
Violations	16	813	866	866	701	671	710	571
	17	18,582	20,354	20,753	17,177	17,256	20,916	23,375
	18	22,068	23,363	24,297	21,693	23,324	30,732	33,445
	19	21,608	22,945	23,618	22,763	23,393	31,230	35,632
	20	20,255	21,470	22,174	21,039	22,829	29,136	33,945
	16-20	83,326	88,998	91,708	83,373	87,473	112,724	126,969
	35-55	189,021	201,239	205,916	187,338	203,546	249,632	291,985
Suspensions	16	387	344	276	219	200	121	98
	17	1,724	1,471	1,547	1,148	1,114	1,039	997
	18	6,199	6,312	5,851	3,812	3,861	3,512	3,623
	19	11,343	11,521	11,694	7,864	7,913	7,429	7,673
	20	14,300	14,072	14,336	10,780	11,266	9,921	10,332
	16-20	33,953	33,720	33,704	23,823	24,354	22,022	22,724
	35-55	174,859	175,209	165,147	148,589	143,805	127,122	137,261
Census	16	106,244	105,756	106,244	121,525	125,353	122,468	120,303
	17	104,535	102,388	104,535	117,379	120,537	124,482	121,750
	18	99,262	100,802	99,262	111,122	113,962	116,797	121,177
	19	104,910	102,147	104,910	102,936	103,052	105,331	108,000
	20	100,060	98,475	100,060	105,495	106,082	106,282	109,082
	16-20	515,011	509,568	515,011	558,457	568,986	575,360	580,312
	35-55	2,613,658	2,575,285	2,613,658	2,792,397	2,794,362	2,790,735	2,785,371

The distributions of violations by year are given in Figure 14. Violation rates for all drivers were relatively constant until 2007-2008 when they increased relative to the previous years. Figure 15-Figure 17 show the percentage distribution of the top teen violations, point-carrying violations, and zero point carrying violations within the total count of violations for teens and adults. The top ten violations accounted for 83% of all teen driver violations and 78% of all adult driver violations. Overall, the distribution of violations for teens and adults were not largely different. However, teen drivers did have a larger percentage of "Careless Driving," "Speeding," and "Unsafe Operation of a Motor Vehicle." There were large differences in the distribution of the zero point-carrying violations for teens and adults. Most notably, a higher percentage of teen zero point-carrying violations were "Unsafe Unsafe Operation of a Motor Vehicle" and adult drivers had a much larger percentage of "Failure to Wear a Seatbelt" violations when compared to teen drivers. Also, it should be noted that "Operating Under the Influence" was one of the top zero point-carrying violations for teens and adults. In New Jersey, if a driver is convicted of operating a vehicle under the influence of alcohol or drugs it does not result in the assessment of violation points. However, other significant penalties are possible including license suspension and possible jail sentencing.

The ten most frequent zero-point violations and point-carrying violations for teen drivers in the pre-GDL era and GDL era are given in Figure 18 and Figure 19. Large changes were seen in the distribution of all violations for teens before and after GDL implementation, particularly with the large increases in the number "Unsafe Operation of a Motor Vehicle" and "Failure to Wear a

Seatbelt" violations in the GDL era. However, the percentage distribution of point-carrying violations was not largely different before and after GDL implementation for teen drivers.

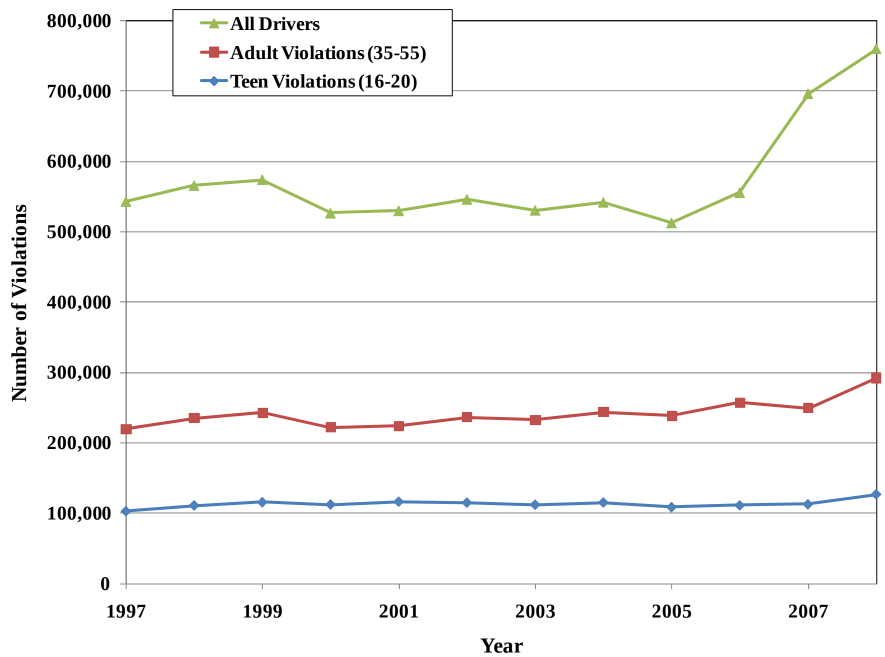

Figure 14. Total number of violations for all drivers, teens and adults in New Jersey (MVC, 1997-2008).

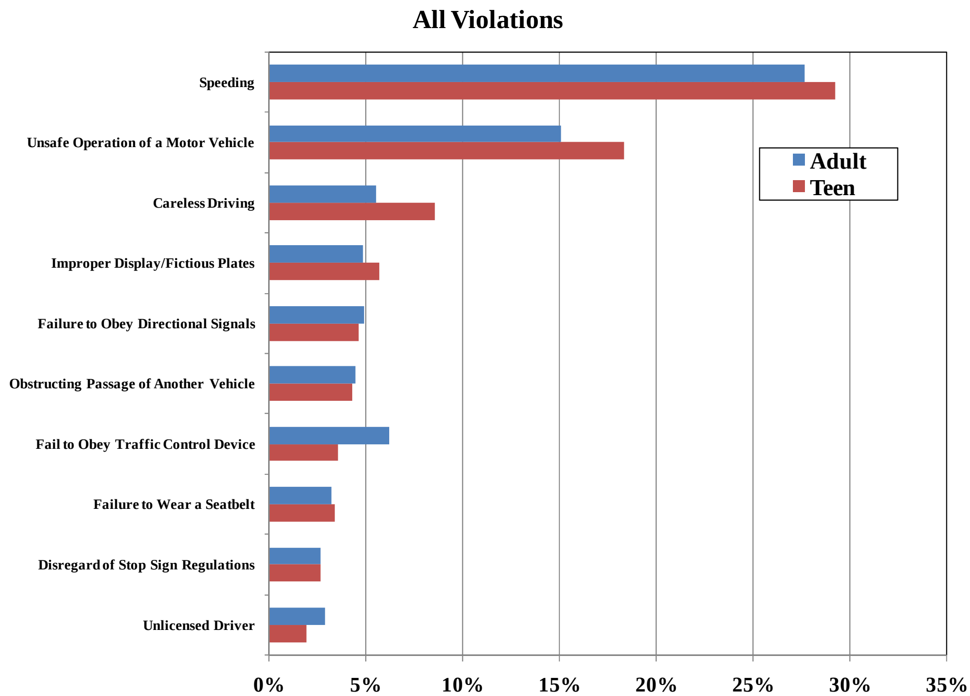

Figure 15. The distribution of the most frequent violations for adult and teen drivers in New Jersey (MVC 1997-2008).

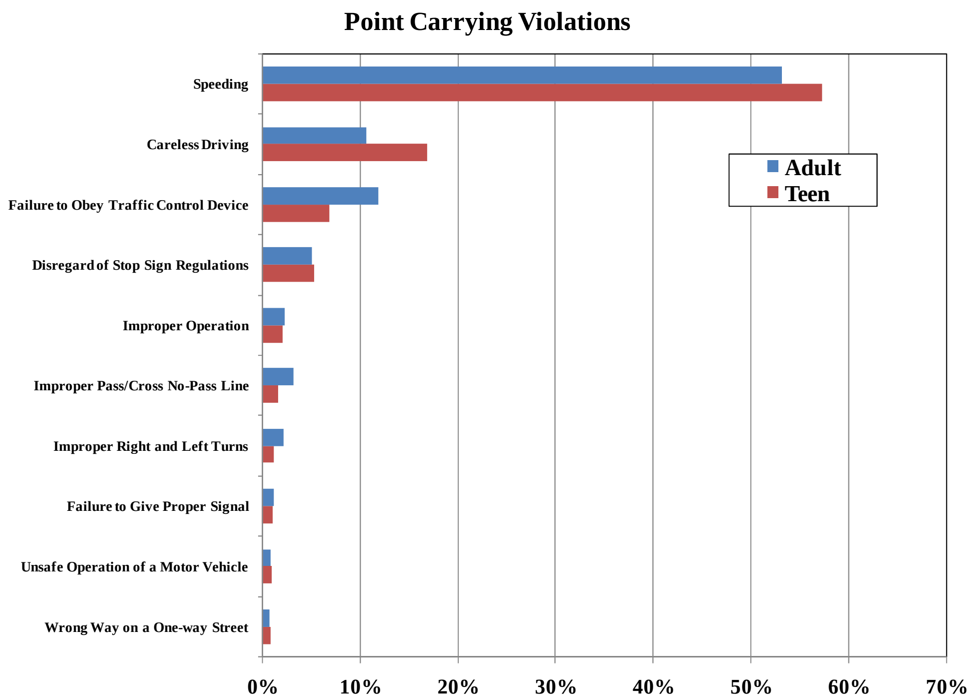

Figure 16. The distribution of the most frequent point-carrying violations for adult and teen drivers in New Jersey (MVC 1997-2008).

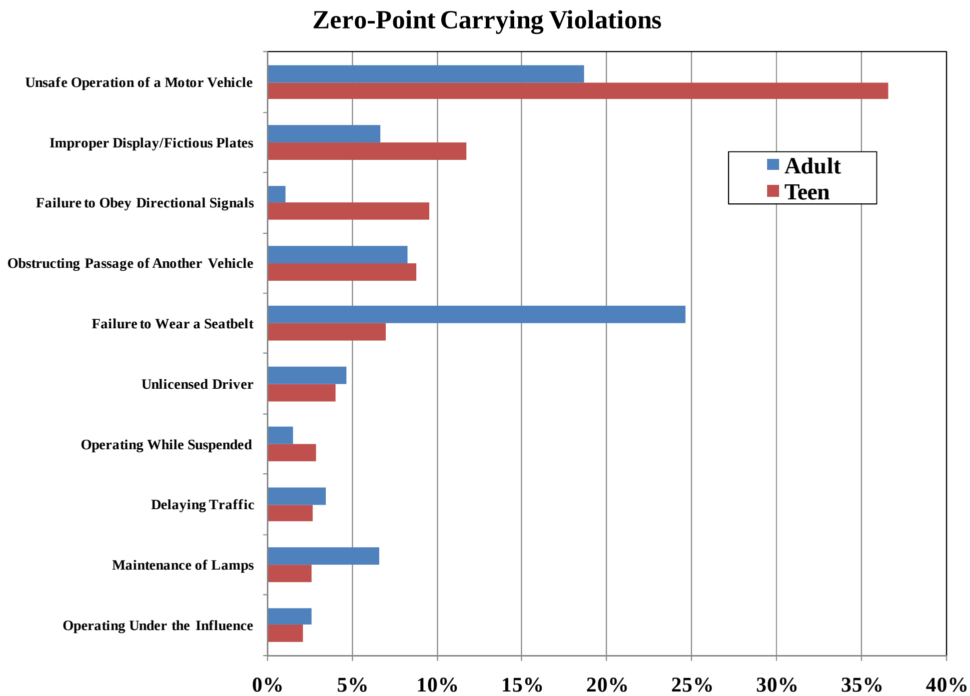

Figure 17. The distribution of the most frequent zero point-carrying violations for adult and teen drivers in New Jersey (MVC 1997-2008).

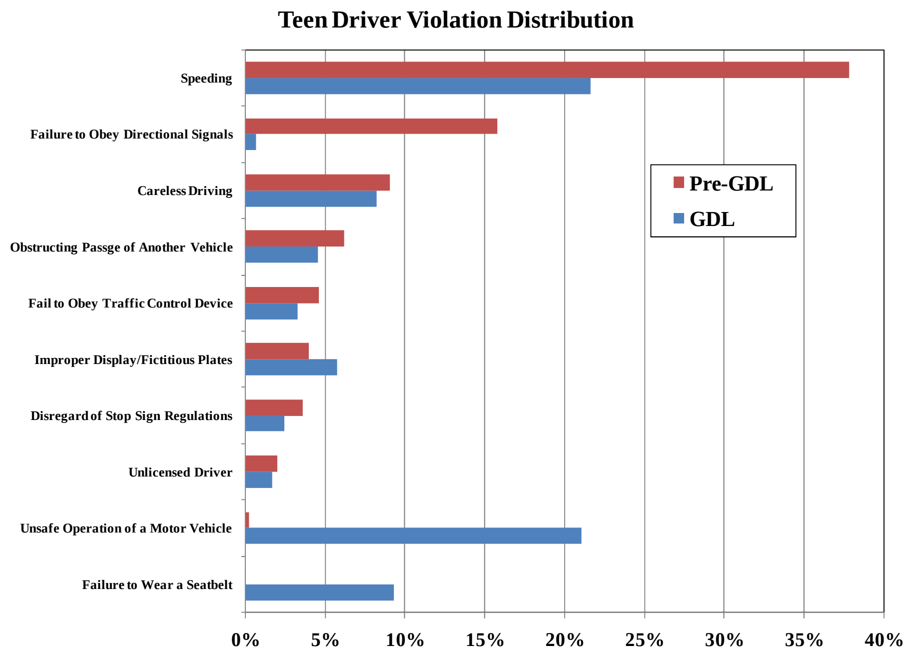

Figure 18. The distribution of the most frequent violations for teen drivers in New Jersey before and after GDL implementation (MVC 1997-2008).

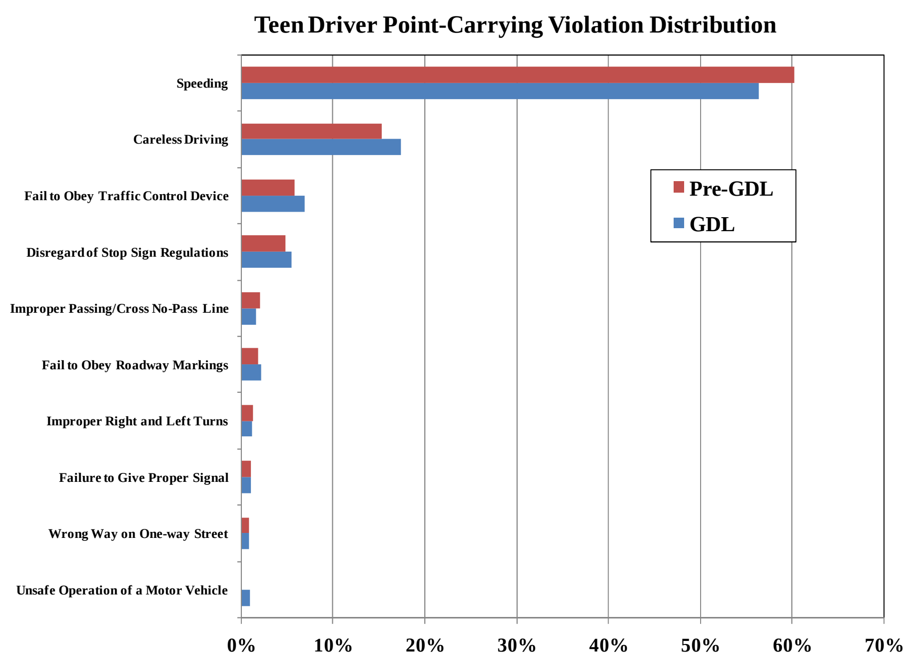

Figure 19. The distribution of the most frequent point-carrying violations for teen drivers in New Jersey before and after GDL implementation (MVC 1997-2008).

The violation rates for teens, relative to adult drivers are given in Figure 20-Figure 22. These show the overall violation rates, zero-point carrying violation rates, and point-carrying violation rates, respectively, for teen drivers. Table 15 gives the relative rates comparing the pre-GDL and GDL periods for all violations, zero point-carrying violations, point-carrying violations, and estimated point-carrying violations based on a Poisson's regression analysis.

The rate of all violations was significantly less in the GDL era for 16 year old drivers. The rate of violations for 17 year old drivers was also less in the GDL era, but this was not shown with statistical significance. The rate of zero-point carrying violations was significantly lower in the GDL era for 16 year old drivers but a significant difference was not seen for any other teen driver age. The rate of point carrying violations was significantly lower in the GDL era for 16 and 17 year old drivers. However, the rate of point carrying violations was significantly higher in the GDL era for 19 and 20 year old drivers after GDL. The estimated point-carrying violation rate in the GDL era was significantly lower for 17 year old drivers but significantly higher for 19 year old drivers.

Figure 23 shows the percentage of violations that were zero-point violations for each age group by year. It was shown that the ratio of zero-point violations to point-carrying violations was higher for 16 year old drivers than for all other ages. Also, this same ratio for 17 year old drivers increased relative to adult drivers after GDL implementation. All drivers showed an increasing zero-point violation to point-carrying violation ratio from 1997-2008, except for 16 year old drivers.

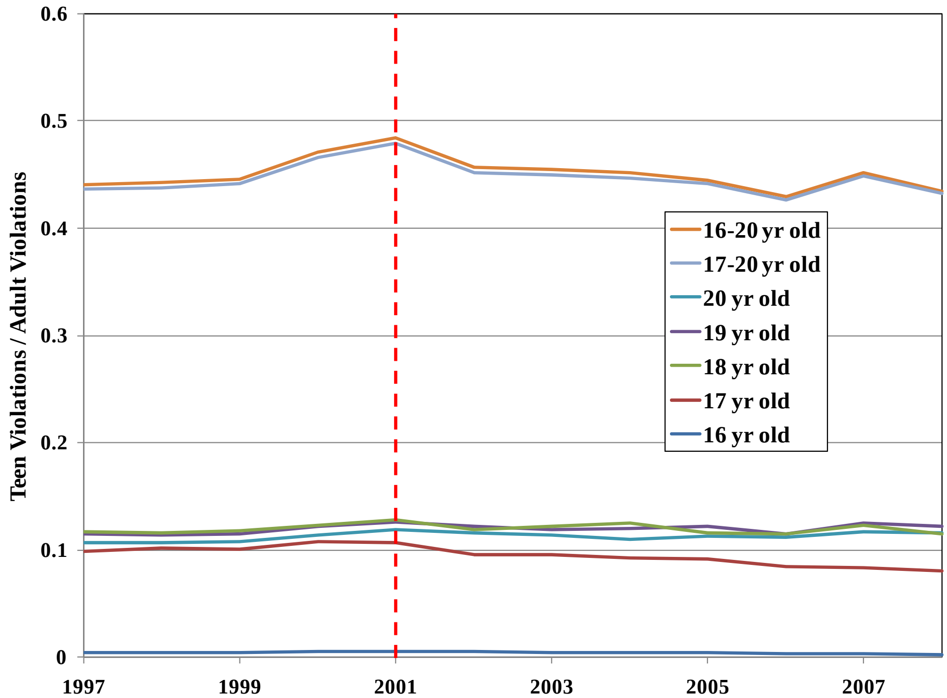

Figure 20. Ratio of teen violations to adult violations in New Jersey (MVC 1997-2008).

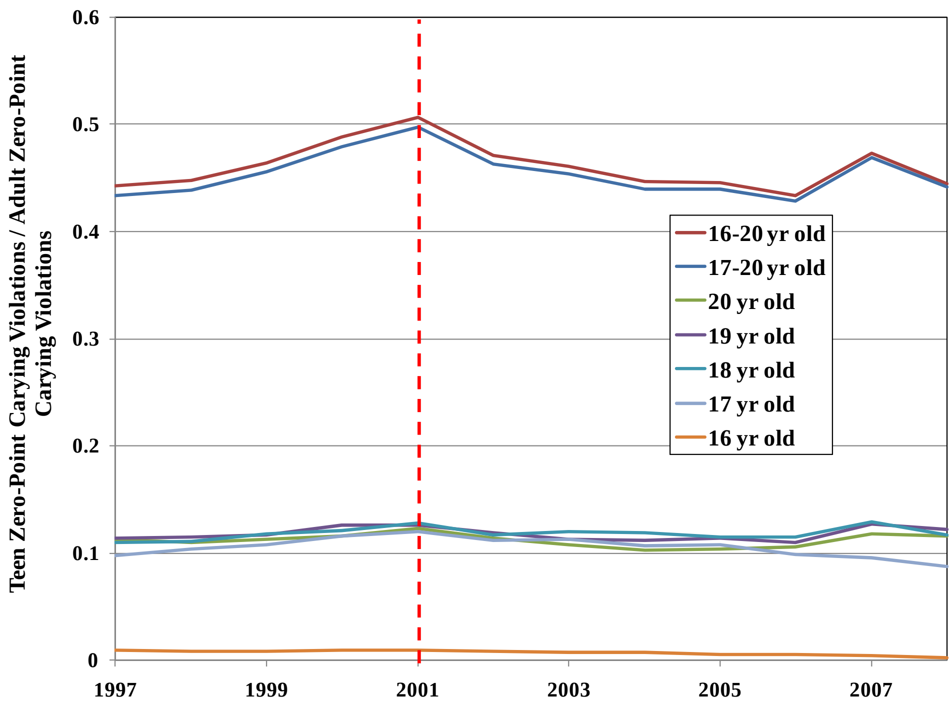

Figure 21. Ratio of teen zero-point carrying violations to adult zero-point carrying violations in New Jersey (MVC 1997-2008).

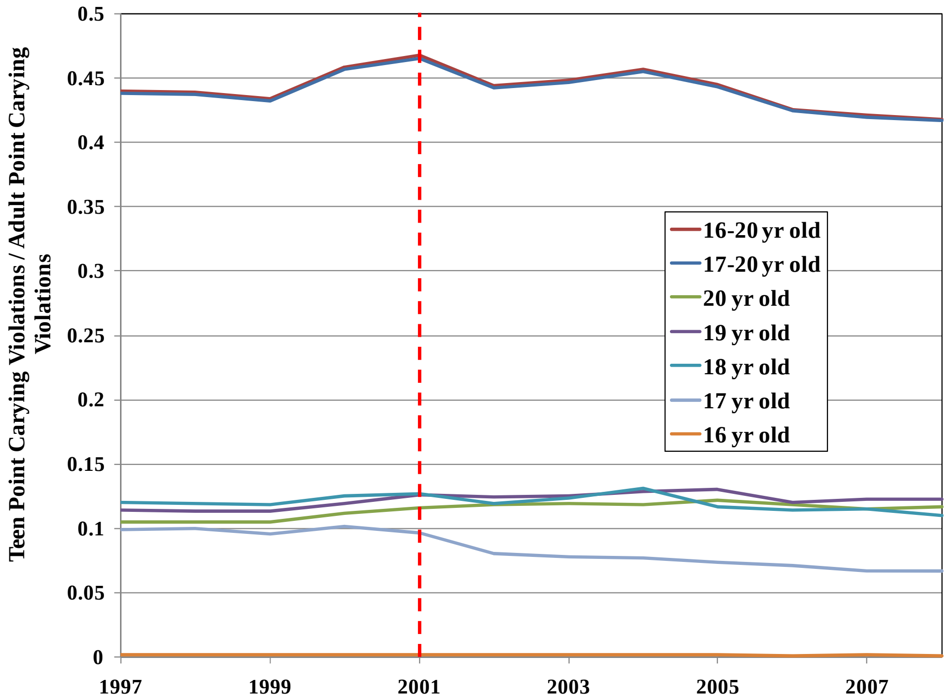

Figure 22. Ratio of teen point carrying violations to adult point carrying violations in New Jersey (MVC 1997-2008).

Table 15.Relative rates of all violations, zero-point violations, point-carrying violations, and estimated point-carrying violations comparing the pre-GDL and GDL era for teen drivers in New Jersey (MVC, 1997-1999 vs. 2005-2008).

	All Violations		Zero-Point Violations		Point-Carrying Violations		Estimated Point-Carrying Violations	
	RR (95% CI)		**RR** (95% CI)		**RR** (95% CI)		**RR** (95% CI)	
16 yr old	**0.705** (0.578-0.860)	*	**0.506** (0.363-0.704)	*	**0.745** (0.604-0.919)	*	**0.906** (0.791-1.038)	
17 yr old	**0.795** (0.641-0.986)	*	**0.887** (0.581-1.354)		**0.662** (0.594-0.738)	*	**0.795** (0.710-0.890)	*
18 yr old	**0.948** (0.730-1.231)		**1.000** (0.618-1.617)		**0.910** (0.818-1.012)		**0.943** (0.858-1.037)	
19 yr old	**1.135** (0.872-1.477)		**1.096** (0.674-1.781)		**1.175** (1.064-1.298)	*	**1.151** (1.055-1.257)	*
20 yr old	**1.072** (0.822-1.398)		**0.997** (0.616-1.614)		**1.139** (1.023-1.267)	*	**1.086** (0.986-1.195)	
16-17 Yr Old	**0.793** (0.636-0.990)	*	**0.860** (0.565-1.309)		**0.664** (0.600-0.736)	*	**0.800** (0.721-0.888)	*
16-18 Yr Old	**0.881** (0.695-1.118)		**0.937** (0.600-1.463)		**0.803** (0.726-0.889)	*	**1.055** (0.966-1.151)	
16-20 yr old	**0.921** (0.844-1.005)		**0.971** (0.611-1.545)		**0.953** (0.862-1.054)		**0.977** (0.896-1.066)	
17-20 yr old	**0.938** (0.814-1.080)		**0.992** (0.624-1.578)		**0.935** (0.658-1.330)		**0.906** (0.791-1.038)	

*-Statistically significant (α = 0.05)

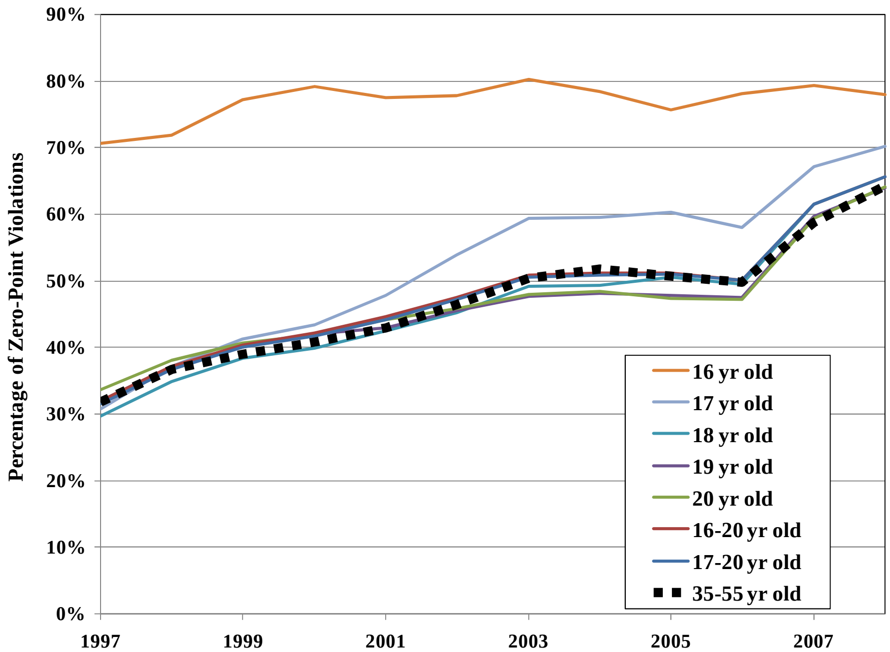

Figure 23. The percentage of violations that were zero-point violations for teen and adult drivers in New Jersey (MVC 1997-2008).

The violations most frequently given to adult and teen drivers from 1997-2008 are presented in Figure 24 and Figure 25, respectively. The point-carrying violations most frequently given to adult and teen drivers are presented in Figure 26 and Figure 27, respectively. Note that the violation listed in the MVC dataset was the amended violation for cases where the driver had the violation changed following a court appearance. Also, the "Unsafe Operation of a Motor Vehicle" violation was not created until 2000. For all violations, it was found that after the "Unsafe Operation of a Motor Vehicle" violation was introduced, it quickly became the most frequently cited violation for both adult and teen drivers, replacing speeding. However, the frequency of "Unsafe Operation of a Motor Vehicle" decreased from 2003-2008 and speeding again became the most frequent violation. "Failure to Wear a Seatbelt" also became a prominent violation for both adult and teen drivers after 2006. "Speeding" and "Careless Driving" were the most frequently cited point-carrying violations for teen drivers. However, the number of speeding violations fell by 39% from 1997 to 2005. The frequency of “Speeding” violations was relatively constant from 2005-2008. For adult drivers, “Speeding,” “Failure to Obey Traffic Control Devices,” and “Careless Driving” were the most frequently cited point-carrying violations.

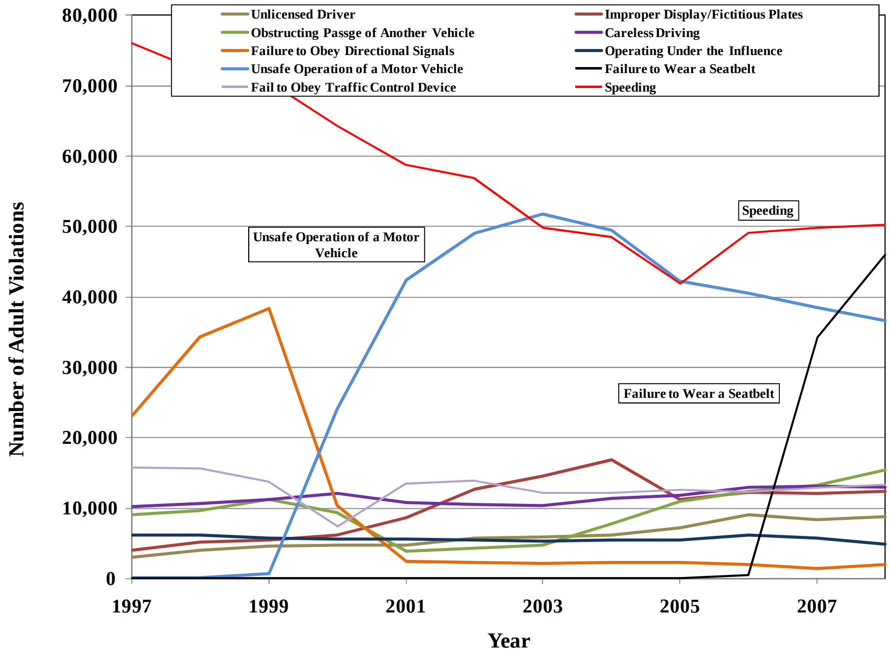

Figure 24. The ten most frequent violations for adult drivers in New Jersey (MVC 1997-2008).

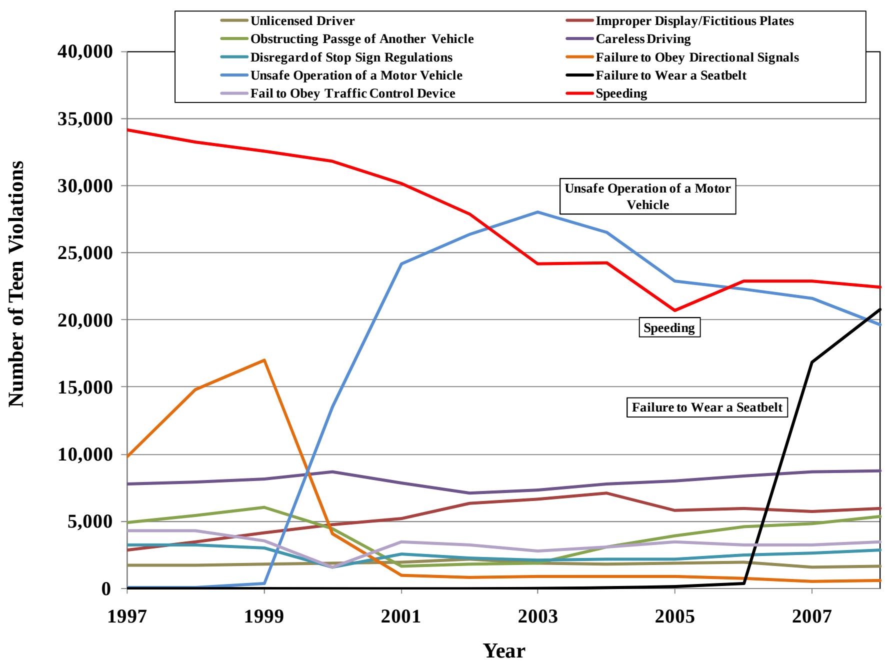

Figure 25. The ten most frequent violations for teen drivers in New Jersey (MVC 1997-2008).

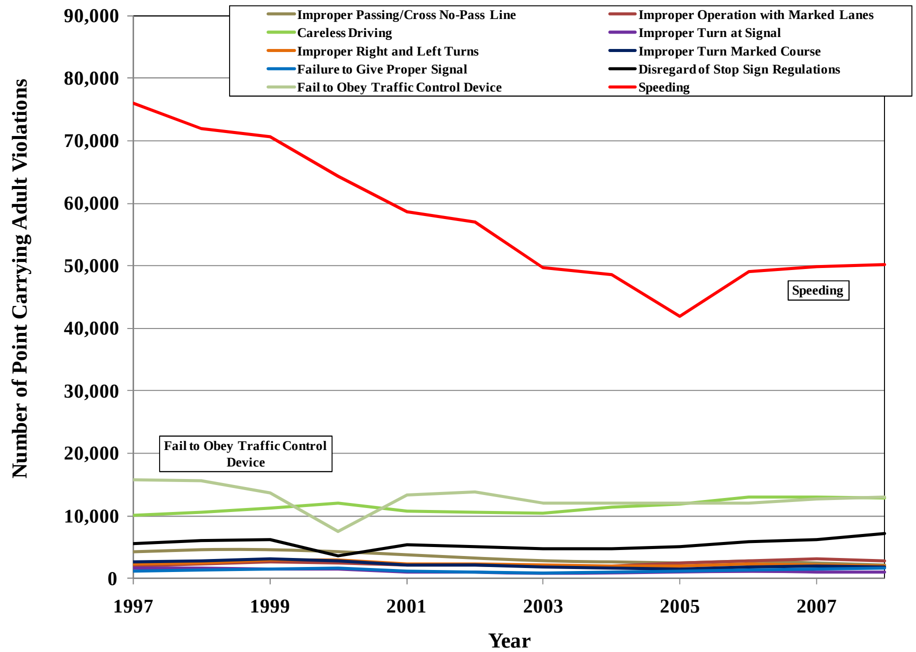

Figure 26. The ten most frequent point carrying violations for adult drivers in New Jersey (MVC 1997-2008).

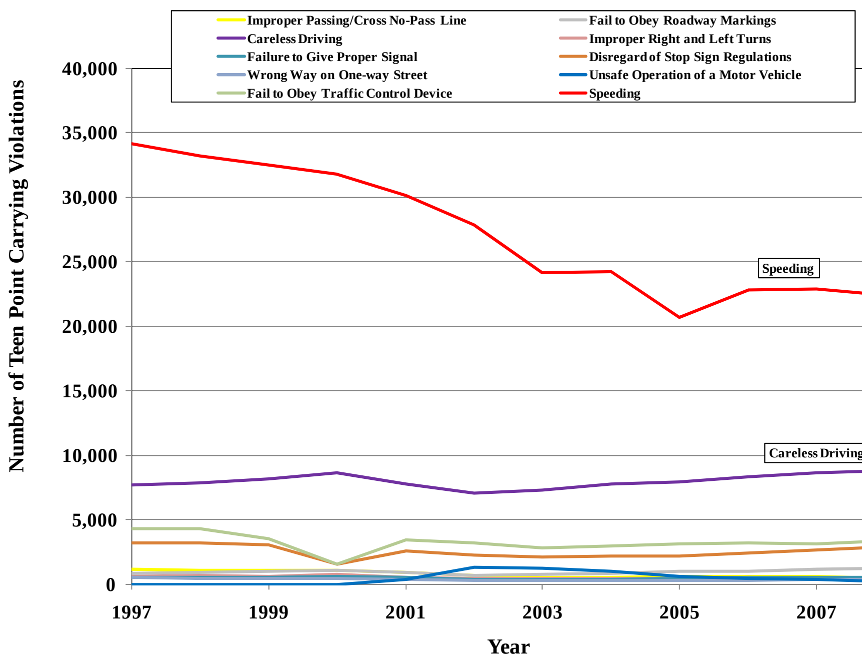

Figure 27. The ten most frequent point carrying violations for teen drivers in New Jersey (MVC 1997-2008).

4.4 Discussion

This study has shown that teen driver violation rates have changed with the introduction of GDL in New Jersey. However, changes in the types of violations appear to be unrelated to the implementation of GDL.

4.4.1 Overall Violation Rates

The total number of violations for all drivers were relatively constant from 1997-2006. However, the number of violations increased significantly in 2007-2008. From an analysis of violation types, it appears that the large increases can be largely attributed to a large increase in the number of "Failure to wear a seatbelt" violations. New Jersey has a track record of seat belt usage rates that are above the national average (NHTSA, 2009). The seat belt usage rate in New Jersey in 2009 was reported as 92.7%; this compares favorably to the national average of 84%. Furthermore, the increase in seat belt usage violations is likely the result of an emphasis placed on enforcement resulting from the state's "Click It or Ticket" campaign.

Relative rates were computed to determine if violation rates had changed for teen drivers licensed in the pre-GDL period as compared to those who were licensed under GDL. It was found that the number of violations per population for 16 and 17 year old drivers was lower in the GDL era when compared to the pre-GDL period, however the result was not statistically significant for 17 year olds. These are the driver ages that would be most affected by GDL regulation. In contrast, there was a statistically insignificant increase in the rate of violations for 19 and 20 year olds. This is contrary to the findings of an analysis performed on the GDL program in Oregon (Raymond et al., 2007). The Oregon study found lower violation conviction rates in the GDL era for all 16-19 year old drivers when compared to one year of data before GDL implementation. However, the Oregon study did not account for the violation rates of an unaffected population, i.e. adult drivers, or changes in population or licensing. These factors may be account for the differences seen in the two studies.

4.4.2 Zero Point Violations

The zero-point violation rate for 16 year old drivers was 49.6% less for teen drivers in the GDL era when compared to the pre-GDL teen drivers. Interestingly, the rate for all 16 year old violations in the GDL era was 29.5% less. The differences in the changes in these two relative rates are a reflection of the change in the proportion of zero-point violations for adult drivers. As seen in Figure 23, the percentage of zero-point violations for adult (35-55 year old) drivers increased from 1997-2008. The same distribution for 16 year old drivers remained relatively constant. The relative rates for teen drivers were computed while accounting for the trends in adult driver violations. Thus, an increase in observed rate for adults would be reflected in a lower relative rate for teen driver groups whose violation rate remained constant.

However, this analysis is only based on violations that occurred prior to September 17, 2008. It was on this date that a directive banned plea agreements for GDL drivers in New Jersey. Carnegie et al (2009) reported that between 2004-2007, 27.7% of violations for all drivers in New Jersey were pleaded to a zero-point violation. As a result, it would be expected that the number of zero-point violations decreased significantly after 9/17/2008 for teen drivers, particularly 16 and 17 year olds. Furthermore, because such a large percentage of 16 year old driver violations were zero-point violations, it is probable that zero-point violation rate for 16 year old drivers will be much less after the plea-agreement ban. However, all 16 year old drivers in the New Jersey GDL program are in supervised driving stage. This stage has been shown to be safer than for teen drivers in the unsupervised stage (Mayhew, 2003). Reasons for the lower crash and fatality rates seen in the supervised driving period have been attributed to the presence and awareness of the supervising driver (Williams et al., 1997). Therefore, it is likely that their violations are less severe in nature due to the direct supervision of an adult. This may be reflected in the high percentage of 16 year old violations that carry no points. Alternatively, the large proportion of zero-point violations for 16 year old drivers could be the result of courts that are more lenient with some GDL drivers because they are aware of the penalties associated with a conviction of a point-carrying violation. However, this theory is not supported by Figure 23, which reveals that the proportion of zero-point violations has remained relatively unchanged from the pre-GDL period to the GDL era.

Many 17 year old drivers would not be under the supervision of an adult driver in the GDL era. As a result, any differences in violation rates seen for 16 and 17 year old drivers may be a reflection of the influence of a supervising adult. Similar to 16 year old drivers, 17 year olds also had lower rates of zero-point violations in the GDL era, but not with statistical significance. Similar to 16 year old drivers, the percentage of 17 year old driver violations that carried no points was higher than for adult drivers. However, while the proportion of zero-point violations remained constant for 16 year old drivers, the proportion of 17 year old zero-point violations increased over time, when compared to adult drivers. In fact, it appears that the proportion of zero-point violations for 17 year olds was similar to that of adults until the GDL regulation was implemented in 2001. After GDL implementation, zero point violations had a larger annual increase for 17 year olds than it did for adult drivers. This suggests that 17 year old drivers, aware of the penalties associated with a point carrying violation, began to take advantage of plea agreements to a greater degree than for other drivers. The rate of zero-point violations for 18-20 year drivers appeared to be unaffected by GDL regulation. For these ages, the relative rates were very close to a value of one. Furthermore, the proportion of zero-point violations was very similar to that of adults for both the pre-GDL and GDL eras. It is also likely that effect of the plea-agreement ban was less for this age group because there were fewer GDL drivers.

4.4.3 Point Carrying Violations

The relative rate of point-carrying violations was significantly lower in the GDL era for 16 and 17 year old drivers when compared to the pre-GDL period. This suggested that teen drivers who were under the regulation of GDL were more careful to follow traffic regulations than their pre-GDL peers. However, analyzing changes in the number of point-carrying violations alone may have been limited in its ability to reflect on teen driver behaviors. Pleading point-carrying violations to zero-point violations was particularly common for teen drivers in New Jersey prior to the ban on plea-agreements (TDSC, 2008). Furthermore, it was shown in Figure 25 that the number of "Unsafe Operator" violations increased significantly after GDL was introduced in 2001. This implied that point-carrying violations were being adjudicated to zero-point violations at a higher rate after GDL implementation. As a result, by only looking at the number of point-carrying violations, the perception of changes in teen driver behaviors resulting from GDL was being clouded.

Our strategy for the effect of plea-bargaining was to combine the number of zero-point violations that were most commonly given as a result of a plea agreement with the total number of point-carrying violations. Presumably, this will provide an estimation of the number of point carrying violations that would have occurred had the plea-bans not been allowed for teen drivers. As a result, it gave a more complete perspective on the behaviors of teen drivers. It was found that the rate of these estimated point-carrying violations was significantly lower for 17 year old drivers after GDL implementation. It is possible that this is a reflection of the penalties associated with a point-carrying conviction. However, it is also possible that the restrictions of GDL have limited the vehicle miles traveled by teen drivers, resulting in fewer violations. In contrast to restricted drivers, the estimated point-carrying violation rate was significantly higher for 19 year olds after GDL implementation. It is possible that teen drivers that have graduated from the GDL program are challenging their recently afforded freedoms, resulting in a greater likelihood of being cited for a violation when compared to those licensed before the regulations of GDL. Alternatively, enforcement may have become stricter for young drivers, regardless of GDL status, relative to older drivers.

4.4.4 Violation Type

The types of violations that teen drivers have been cited for has changed over time, but these changes are not necessarily a direct result of GDL regulation. For instance, a large increase in the number of “Unsafe Operation” violations for teen drivers was seen in 2000, before GDL implementation. A similar increase was seen for adult drivers in 2000 as well. Since 2000, “Unsafe Operation” has become one of the most commonly cited violations and is the most common zero-point amended violation following a plea-agreement in New Jersey (Carnegie et al., 2009). Further evaluation of New Jersey violations will be needed to determine if the number of "Unsafe Operation" violations decreased significantly for teen drivers after plea agreement ban.

In 1997, the most common violation for both teen and adult drivers was "Speeding." This was overtaken by "Unsafe Operation" in 2003. Carnegie et al (2009) showed that speeding violations were the most commonly amended violations for all drivers in New Jersey from 2004-2007. The decrease in the number of "Speeding" violations and increase in "Unsafe Operation" violations are likely related. Figure 23 showed that the percentage of zero-point violations, i.e. pleaded violations, has increased since 1997. Also, the MVC database only reports the amended violation in plea agreement cases. Therefore, it is probable that many of the speeding violations are being pleaded to a zero-point carrying violation.

Other than speeding, the annual distribution of point-carrying violation types appeared to be relatively unchanged for both teen and adult drivers over the 1997-2008 time period. Overall, teen drivers had the highest proportion of "Speeding" and "Careless Driving" violations. These violation types may reflect the inexperience and/or risk taking that is often attributed to a higher young driver crash risk (McKnight and McKnight, 2003; Williams, 2003). Interestingly, the percentage distributions of point-carrying violations for teen drivers were largely the same before and after GDL implementation. The implications of this are not completely clear. It is possible that, given that a teen received a violation, the types of behaviors that led to traffic violations for teen drivers did not change as a result of GDL. Ideally, however, the number of teens receiving violations would have decreased with GDL implementation.

This hypothesis, however, is not supported by Figure 27, which shows that the annual number of point-carrying violations for teen drivers has not changed since GDL implementation, with the exception of “Speeding”. The number of point-carrying violations would presumably have been less after GDL if most teen drivers were indeed behaving differently as a result of the regulations. Instead, the point-carrying violation rates that are presented in Table 15 show that while the rate of point-carrying violations may have been lower for restricted drivers, a corresponding increase in the point-carrying violation rate was seen for 19 and 20 year old drivers after GDL implementation.

4.4.5 Implications

Many of the violation trends seen for teen drivers were also observed for adult drivers. This suggests that there were indeed changes in the way the violations were administered and pleaded from 1997-2008 for all New Jersey drivers. As a result, it was necessary to account for changes in adult driver violation trends when considering the changes in the violation trends for teen drivers. These methods were not employed by other studies that investigated changes in violation rates associated with GDL programs and may be the reason for the differences seen in their effectiveness measure and ours.

Neither, the previous studies nor our study was able to determine if the changes in violation rates were the result of changes in teen driver behavior resulting from effective GDL regulations or if simply the result of fewer vehicle miles traveled by teen drivers after GDL. This exposure reduction hypothesis is supported by the fact that the types of violations for teen drivers did not appear to change as a result of GDL regulation. Instead, changes in the distribution of teen driver violations over time paralleled those for adult drivers; adult drivers were unaffected by GDL regulation. As a result, the reductions in violation rates for GDL aged drivers (16 and 17 years old) may simply be a reflection of reductions in exposure. Unfortunately, age-specific exposure data, e.g. vehicle miles traveled, were not available for New Jersey drivers. Therefore, an analysis of this hypothesis was not possible.

Interestingly, the estimated point-carrying rates for 19 year old drivers were significantly higher after GDL implementation, suggesting that GDL graduates had actually become less careful drivers than their pre-GDL peers. However, the lack of a significant difference in the rate of estimated point-carrying violations for 20 year old suggests that this may have been a temporary phenomenon.

4.4.6 Limitations

The MVC database contained the amended records of drivers who had pleaded to lesser violations following a court appearance. No record of the original violation was available. As a result, it was not possible to identify the distribution of violation types for violations that were amended. Knowledge of the original violation would provide a clearer perspective of the true nature of teen driver behavior. Furthermore, it would help to identify the types of violations that were amended most frequently before and after GDL regulation.

When computing the estimated point-carrying violation counts, it was assumed that all “Unsafe Operator”, “Obstructing Passage of another Vehicle”, “Delaying Traffic”, and “Failure to Obey Directional Signals” violations were the result of point-carrying violations that were pleaded to zero-point violations. This assumption may not be true for all cases. However, our understanding of these violation types, particularly “Unsafe Operation”, is that they are generally given as a result of plea-agreements.

The violation data from 2008 was scaled to represent an entire year. It was assumed that the distribution of violations up to September 17, 2008 would be representative of the violation distribution for the remainder of the year. The violation counts up to this date were compared to the violation distributions for the years before 2008. The distribution of violations prior to this date in previous years was calculated and found to be similar to the inverse of the scaling factor. The applied scaling factor (261/366) assumed that 71.3% of all violations occurred prior to September 17 in 2008. This compared to an average of 73.0% for all other years. As a result, it was assumed that the scaling factor represented an appropriate assumption.

Finally, an induced exposure approach was utilized to account for changes in the driving environment for all drivers that are unrelated to GDL implementation. An underlying assumption of this approach is that the ratio of exposure, e.g. vehicle miles traveled, for teen and adult drivers would have remained constant with time. However, it is possible that the travel exposure of teen drivers decreased after GDL implementation as a direct result of the restrictions that were instituted as part of the program. Unfortunately, age-specific VMT was not available for New Jersey drivers so a check of this assumption was not possible.

4.5 Conclusion

The rate of traffic violations for 16 and 17 year old drivers, those who are most affected by GDL regulation, was lower after GDL implementation as compared to their pre-GDL peers, although the result was not statistically significant for 17 year old drivers. The violation rates for 18-20 year old drivers were not significantly different between the two time periods. However, 19 year old drivers did have a significantly higher rate of estimated point-carrying violations after GDL implementation. To the extent that violations reflect teen driving behavior, GDL appears to have been of a benefit to 16 and 17 year old drivers in New Jersey.

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5. Evaluating the Effect of Eliminating Plea Agreements on Teen Drivers in New Jersey

5.1 Introduction

If a teen driver in a GDL program commits a traffic violation or fails to comply with a GDL restriction (e.g nighttime driving, cell phone use), many U.S. GDL programs assess driver privilege penalties. In New Jersey, the accumulation of violations can result in three sanctions: 1) a postponement of advancements through the GDL program, 2) require participation in a safe driving course, or 3) license suspension. Currently, these penalties are triggered when violation points are accumulated by a teen driver. In the event that a teen driver is convicted of a violation that carries two points, a warning letter is sent to the driver to instruct them that if they are convicted of another point carrying violation while a GDL driver, they will be subject to further penalty. Following the accumulation of three or more points while holding a GDL license, the driver is required to participate in a four hour probationary driver program (PDP) safe driving course. After the completion of this course, the GDL driver is given a credit of three violation points on their record, but subjected to a 12-month probationary period. During this time, if the driver is convicted of another point carrying violation, their license will be suspended.

Despite the existence of this GDL penalty program, problems have been identified in this point-based monitoring approach. The TDSC Report found that the system that was in place to track the violations of teen drivers was limited in its principal role. First, certain violations, such as failing to wear a seat belt, result in a fine but no points on the license. As a result, the infraction would not count towards a GDL sanction, despite the fact that belt-use by all passengers in a GDL driven vehicle is required and is the responsibility of the GDL driver, per GDL regulation. Furthermore, many teens were pleading to a lesser charge of "Unsafe Operator" when a more severe violation was originally assessed. "Unsafe Operator" carries a fine and no points, and as a result will not count towards GDL sanctions for the teen driver. In response to this practice, the New Jersey Attorney General disallowed plea agreements that resulted in point-carrying violations being reduced to non-point carrying violations for all GDL drivers, effective on September 17, 2008 (Milgram, 2008). The ban on plea agreements was meant to be a temporary solution until an event based system can be instated. An event based system is being developed by the New Jersey Motor Vehicle Commission (NJ MVC) that will track all violations of all drivers in the GDL program, regardless of points.

If the large majority of GDL drivers were taking advantage of the plea agreement option, then any effect on the driving behavior of teens when this opportunity is removed may be reflected in decreased crash and violation rates. It is possible that teen drivers have become more conscientious drivers when presented with the threat of unavoidable repercussions resulting from GDL violations.

Objective Determine the effectiveness of a plea bargain ban on violation and crash rates for teen drivers in New Jersey.

5.2 Methods

The approach of this study was to compare teen driver traffic violation rates and crash rates before and after the directive eliminating plea-agreements for teen drivers in the GDL program. Interestingly, by instituting this plea-agreement ban, two distinct GDL driving populations have been created; GDL driving before the ban and GDL driving after. This provides a unique opportunity to determine the effect of the ban, separate from other GDL regulations. Shope (2003) noted that it is difficult to determine which restrictions associated with GDL programs have been most effective because they are generally instituted as a total package.

This study contains three analyses that identify changes associated with the ban on plea-agreements: 1) The Administrative Office of the Courts (AOC) records in New Jersey were used to identify the extent of the plea-agreement problem before the ban, 2) The NJ MVC dataset was used to determine the effect on violation rates and violation types for teen drivers, and 3) the NJCRASH dataset was used to determine the effect on teen driver crashes.

5.2.1 Datasets

The NJCRASH database is a collection of all police reported crashes in New Jersey from 1997-2009. This database contains information regarding the circumstances of the crash as well as occupant information. The NJ MVC dataset is a collection of all traffic citations and events related to any subsequent penalties. Events in the system included warning notices for point accumulations, suspension scheduling, traffic violations, and crashes for each licensed driver in the state who recorded at least one of these events. The AOC dataset that we obtained consisted of all amended violations in New Jersey. Included in the dataset was information corresponding to the amended violation including the original violation code, amended violation code, the event date, and the court appearance date. This allowed us to perform an analysis of plea-agreement violation trends in New Jersey. Furthermore, the birth month and birth year are coded into the driver's license number in New Jersey. Therefore, it was possible to conduct an age-specific analysis of the plea-agreement trends despite the lack of a given age or date-of-birth field in the dataset. As a result, the age of the driver at the time that the violation was originally given was computed. For confidentiality, the date of birth code was pulled from the Driver License Number and a random driver record number was assigned to each record. The final dataset that we used for all analyses included no personal identifiers and the original dataset was stored in a separate, secure location.

The availability of data from each dataset is varied. The AOC dataset contained amended violation records for November 1, 2004-November 30, 2007. Therefore, it was not possible to compare the violation trends before and after the implementation of the plea-agreement ban. Nonetheless, it was possible to identify the trends associated with plea-agreements for teen drivers before the implementation of the ban. The NJCRASH data was available from 1997-2009. The NJ MVC dataset contained the driver records of all licensed drivers in the state who had at least one recorded event between January 1, 1986 and March 31, 2010. For these datasets, driving populations were defined as either pre- or post-plea agreement ban. The pre-ban population consisted of events that occurred in 2005-2008. The post-ban population included events that occurred in 2009. To ensure that the comparison populations were similar in their exposure, only crashes and violations that occurred before September 17, (the date that the plea-agreement ban was enacted in 2008) for each year were included. Also, the statistical methods used compared the annual violation or crash counts directly. Therefore, it would not be appropriate to compare full year counts (2005-2007 and 2009) to a partial year (2008). The resulting driving populations are presented below:

- **Pre-Ban** – January 1 – September 17: **2005 – 2008**
- **Post-Ban** – January 1 – September 17: **2009**

For a driver to be included in any of the crash rate analyses, they will have to have been licensed in New Jersey. This was to ensure that any derived effectiveness calculations were with respect to drivers licensed in New Jersey only.

5.2.2 Data Analysis

Our analysis of teen violation and crash rates sought to identify trends by directly comparing the pre-ban and post-ban driving populations. This allowed us to identify the changes in teen driver behaviors in New Jersey that corresponded with the enactment of the plea-agreement ban.

While older drivers have been included in previous studies, it was not deemed appropriate for a plea-agreement analysis at this time. In New Jersey, 18-20 year old drivers may be subject to GDL regulation. However, it was not possible to determine the licensing status of each driver. Therefore, this study was restricted to 16-17 year old drivers only because it was known that they were all GDL drivers. Furthermore, only one year of data post-plea ban was available and thus, an analysis of the long-term effects for GDL graduates in New Jersey, as has been performed in the previous studies, was not possible. Methods were taken to normalize teen driver violation and crash rates by those of adult drivers, defined as 35-55 year olds. This approach provided a comparison population (adult drivers) consisting of an age range where the drivers were not subject to the GDL regulations, but were assumed to have been exposed to the same driving environment. Relative rates were computed that compared the violation and crash rates of pre-ban and post-ban teen drivers. A relative rate greater than one indicates the teen drivers had a higher violation or crash rate in the post-ban era as compared to the pre-ban era, while accounting for overall violation and crash distribution trends (i.e. the corresponding adult rate).

A Poisson's distribution was assumed for the violation and crash counts and a regression equation was applied to compute 95% confidence intervals for all relative rates. Applying a Poisson regression model to the dataset allowed us to account for the crash and violation trends of adult drivers. Driver age (teen vs. adult), plea-ban time period (pre-ban vs. post-ban), and an interaction predictor for these two variables were included in the regression model. Furthermore, age-specific population counts, obtained from the U.S. Census Bureau, were included as an offset in the regression model (USCB, 2010). The complete regression model is shown in Equation 5.

$$log\left(\frac{Violations}{Population}\right) = \beta_0 + Driver\ Age(x_{age}) + Plea\ Era(x_{Plea}) + Age/Plea(x_{age/Plea})$$ **Equation 9**

$$Relative\ Rate = \frac{\left(\frac{Teen\ Violations}{Population}\right)_{Post-ban}}{\left(\frac{Teen\ Violations}{Population}\right)_{Pre-ban}}$$ **Equation 10**

Each regression coefficient was determined through a least-squares analysis. Relative rates were computed through the exponentiation of the regression coefficient for the teen driver/plea-ban interaction. The relative rates express the ratio given in Equation 6. To properly compute the confidence intervals, a negative binomial distribution was assumed to compute the variance within the violation populations and to account for overdispersion within the data distribution. Overdispersion occurs when the variation about a fitted value is greater than what is consistent with the Poisson distribution (i.e. the variance of the fitted variable is not equal to the mean). The negative binomial compensates for the level of overdispersion within the model and computes the variance accordingly (Berk et al., 2007). The SAS v9.2 software was used for all database analyses and statistical computations (SAS, Cary, NC). The analyses were conducted on all teen driver violations, zero-point carrying violations, all point-carrying violations, and severe violations (i.e. greater than 4-point carrying violations). Relative crash rates were computed as well. Unfortunately, the licensing status of the teen drivers was not available in the dataset so it was not possible to conduct an analyses based on license status.

The MVC dataset contains records of interventions, i.e. warning letters, license suspensions, and driver improvement program attendance, associated with the accumulation of violations. As a result we were able to compute the relative rates of GDL penalties and warnings that compared the pre-ban and post-ban populations. These analyses included rates of probationary driving courses for teen drivers, the rate of point accumulation warning letters for teen drivers, and the rate of suspensions for teen drivers. This provides perspective on the effect that plea-agreements have had on the ability of the point-based GDL penalty system to appropriately assess sanctions as they were originally intended. The average rates from the pre-ban period were compared to the post-ban period. A Student t-test was used to determine if the number of interventions in the pre-ban period was significantly different than the post-ban period, i.e. the null hypothesis was that the pre-ban rates were the same as the post-ban rate. These counts were not compared to those of adults because GDL drivers are subject to different interventions.

The AOC dataset allowed us to identify the ways that teen drivers had been using the plea-agreements to circumvent the penalties built into the GDL legislation. Specifically, we were able to identify the most amended violations as well as identify which violations were most commonly amended, i.e. the original violations. This also helped to explain changes in the violation frequencies that were seen in the MVC database from the pre-ban to post-ban periods. The New Jersey drivers license number contains the driver's birth month and birth year. In order to compute the age of drivers in the AOC dataset, the drivers license number had to be decoded. However, not all records in the dataset contained a full license number. In other cases, the license number was in an unknown format. In all, 84% of the records had a full driver's license number and were used in the analysis. It was assumed that the distribution of the violations from the records with a full license number were representative of all the amended violations.

5.3 Results

The total number of violations for teens and adults are given in Figure 28. The number of violations generally increased from 2005 to 2008, but decreased for both teens and adults in 2009. This indicates that there were changes in the manner in which violations were given, post-plea ban, that were not related to the ban itself.

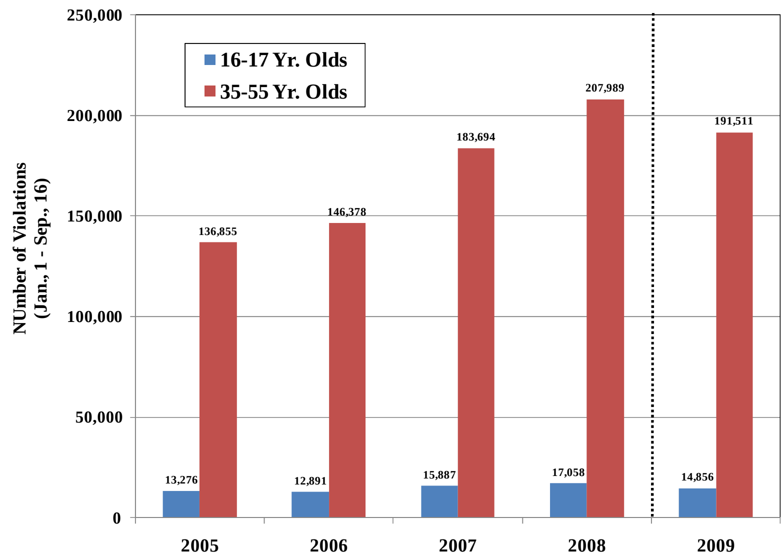

Figure 28. Violation counts for teen and adult drivers from January 1, - September 17 for each year (MVC, 2005-2009).

The relative rates of all violations, violations that carry no points, point-carrying violations, and 4+ point-carrying violations are given in Table 16. Overall, the number of violations was lower after the plea-ban for teen drivers, but was only statistically significant for 16 year old drivers. Similarly, the rate of zero-point carrying violations was lower in the post-ban period when compared to the pre-ban period, but again only significantly for 16 year old drivers. In contrast, the number of point-carrying violations was higher in the post-ban period, but only with statistical significance for 17 year old drivers. There was no statistically significant change in the rate of 4+ point-carrying violations for teen drivers. Table 17 shows that there was a corresponding reduction in the crash rate from the pre-ban period to the post-ban period. However, the relative rate of crashes was not shown with statistical significance when comparing the two periods with the exception of the rate of single vehicle crashes for 16 year old drivers.

Table 16. Relative rates comparing the violation distributions of teen drivers before and after a ban on plea-agreements (MVC, 2005-2009).

	All Violations		Zero-Point Violations		Point-Carrying Violations		4+ Point Violations
Age	**RR** (95% CI)		**RR** (95% CI)		**RR** (95% CI)		**RR** (95% CI)
16	**0.42** (0.24-0.72)	*	**0.27** (0.13-0.59)	*	**1.00** (0.67-1.51)		**0.54** (0.17-1.73)
17	**0.89** (0.53-1.49)		**0.65** (0.29-1.48)		**1.43** (1.24-1.66)	*	**1.19** (0.72-1.98)
16-17	**0.88** (0.52-1.49)		**0.64** (0.28-1.46)		**1.44** (1.25-1.66)	*	**1.19** (0.72-1.99)

Table 17. Relative rates comparing the crash distributions of teen drivers before and after a ban on plea-agreements (MVC, 2005-2009).

	All Teen Crashes	Single Vehicle Teen Crashes		Teen Drivers in Crashes
Age	**RR** (95% CI)	**RR** (95% CI)		**RR** (95% CI)
16	**0.87** (0.73-1.04)	**0.78** (0.61-0.99)	*	**0.88** (0.73-1.05)
17	**0.94** (0.84-1.06)	**0.94** (0.83-1.06)		**0.95** (0.84-1.07)
16-17	**0.95** (0.85-1.05)	**0.94** (0.84-1.05)		**0.92** (0.87-0.98)

The top 10 violations for teen drivers were computed for the pre-ban period. The annual distributions of these violations for both the pre- and post-ban periods are given in Figure 29. It is seen that “Unsafe Operation” was the most prevalent violation until the plea-agreement ban was implemented in 2008. Furthermore, corresponding increases in the number of speeding and careless driving violations were seen in 2009 when compared to the pre-ban period. The increase in “Failure to Wear a Seat Belt” and “GDL Regulation Non-compliance” violations was seen prior to the plea-agreement ban. As a result, these changes were not likely to be related to the plea-agreement ban and were more likely due to increased enforcement. In fact, a similar increase the "Failure to Wear a Seat Belt" violation was seen for adult drivers as well.

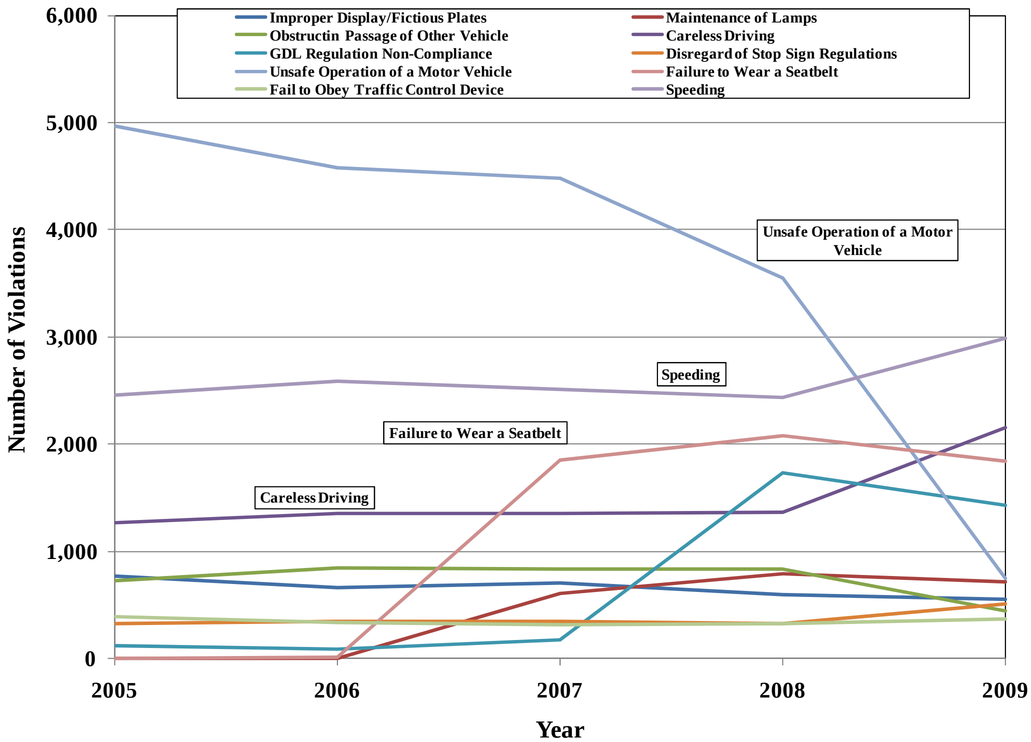

Figure 29. The top ten teen driver violation types by year (MVC 2005-2009).

Based on an evaluation of the AOC data, more violations were pleaded to "Unsafe Operation" than any other violation before the plea-agreement ban, as shown in Table 19. Of the pleaded violations, the most common were "Speeding" and "Careless Driving" as shown in Table 18. These two violations types were also among the top 10 amended violations. Seven of the ten most frequent original violations were point-carrying violations. Alternatively, only two of the top ten amended violations were point carrying violations.

Table 18. Top 10 original violation types given for 16 and 17 year old drivers in New Jersey (AOC, 2004-2007).

Violation	Count	%	Points
Speeding	17,420	42%	2/4/5
Careless driving	10,827	26%	2
Failure to obey stop or yield signs	2,513	6%	2
Failure to observe traffic signal	1,864	4%	2
Reckless driving	1,062	3%	2
Driving without Insurance	956	2%	0
Improper Passing	901	2%	4
Driving with an expired license	627	1%	0
Failure to observe traffic lanes	617	1%	2
Violation of GDL Restrictions	388	1%	0
Total	**41,820**	**100%**	-

Table 19. Top 10 amended violation types for 16 and 17 year old drivers in New Jersey (AOC, 2004-2007).

Violation	Count	%	Points
Unsafe Driving	25,306	61%	0
Speeding	6,582	16%	2/4/5
Obstructing passage of vehicles	3,448	8%	0
Failure to possess ID, registration, or insurance card	1,776	4%	0
Careless driving	1,310	3%	2
Vehicle in unsafe condition	458	1%	0
Use of a cell phone while driving	440	1%	0
Delaying traffic	436	1%	0
Driving with an expired license	389	1%	0
Failure to Report Accident	284	1%	0
Total	**41,820**	**100%**	-

The higher rate of point-carrying violations in the post-ban period, compared to the pre-ban period, corresponded to an increase in the number of point accumulation warning letters sent to teen drivers in the post-ban period as shown in Table 20. Similarly, the number of 17 year old drivers who were required to attend a PDP driving course was significantly higher in the post-GDL period. If a GDL driver is convicted of another point carrying violation in the 12 month probationary period following their attendance in a PDP class, a suspension order is given. Interestingly, despite increases in the number of point-carrying violations and the number of PDP class attendants, the number of suspension orders was found to be significantly less in the post-ban period as compared to the pre-ban rates for 16 and 17 year old drivers.

Table 20. Probationary Driver Program (PDP) activities for teen drivers before and after a ban on plea-agreements (MVC, 2005-2009).

	Age	2005	2006	2007	2008	2009	% Change	P-value	
Point Accumulation Notices	**16**	59	38	44	27	70	**67%**	0.0247	*
	17	3,463	3,652	3,614	3,421	4,964	**40%**	0.0001	*
PDP Classes	**16**	5	3	0	1	1	**-56%**	0.3416	
	17	372	394	432	362	624	**60%**	0.0006	*
Suspension Orders	**16**	175	144	95	70	37	**-69%**	0.0381	*
	17	807	772	756	710	530	**-30%**	0.0014	*

5.4 Discussion

Based on the findings of this study, the ban on plea-agreements for GDL drivers in New Jersey appears to have reduced the number of teen driver violations while increasing the number of GDL interventions associated with accumulation of violation points. The implications of these findings are presented in the following section.

5.4.1 Violation rates

It was found that the overall number of violations for 16 and 17 year old drivers was lower after the implementation of a plea-agreement ban. However, the result was only statistically significant for 16 year old drivers. The effect of the plea-agreement ban was more directly apparent in the rate of point-carrying violations for 16 and 17 year old drivers. The order given by the Attorney General of New Jersey states that GDL drivers were no longer allowed to plead a point-carrying violation to a non-point-carrying violation. The number of point-carrying violations was significantly greater after the ban was enacted when compared to the pre-ban period. In contrast, the number of zero-point violations was shown to be less in the post-ban period when compared to the pre-ban period. These results suggest that the ban has been effective in eliminating the loop-hole that teen drivers had been utilizing to circumvent the GDL penalties that are part of the regulations.

Studies concerning the effectiveness of GDL violation penalties are largely absent from the literature. This is particularly interesting because all states have penalties associated traffic violations or GDL restriction noncompliance for GDL young drivers (Ferguson, 2003). This is most likely due to the issues that have been presented previously. First, there have been very few studies on the violation rates of teen drivers, largely due to limited access to the violation data. Also, it is difficult to parse out which GDL regulations are effective and to what extent they contribute to the overall effectiveness when multiple regulations are instituted as a package. This is the first study to suggest that the penalties associated with traffic violations for GDL drivers do indeed decrease the violation rates for teen drivers. The fear of repercussions may have resulted in changes in the attitudes and behaviors of teen drivers. The threat of rigorously enforced GDL regulations may have led to a more conscientious and law-abiding teen driver. This hypothesis is supported by the overall reduction in violations.

5.4.2 Violation Points

While the change in the overall rate of violations indicates that the plea-ban has changed teen driver behaviors, it is not possible to directly correlate the changes to the ban itself. However, the changes in the rates of point-carrying violations and zero-point carrying violations directly reflect the influence of the mandate. Unfortunately, statistical significance was not shown for the relative rates for all comparisons. However, other indicators point to the direct effects of the plea-ban. For instance, "Unsafe Operation" was the most common violation for teen drivers prior to the plea-agreement ban. After the ban was implemented, the rate fell by 83% compared to the pre-ban period. This indicates that the plea-agreement ban was successful because the "Unsafe Operation" violation was the most commonly pleaded violation for teen drivers, as shown in Table 19. Furthermore, prior to the implementation of the ban, the most common violations that were amended for teen drivers were speeding and careless driving. The rates of these violations increased by 20% and 62%, respectively, after the ban was implemented.

5.4.3 Probationary Driver Program (PDP)

While increases in the assessment of points for teen drivers may serve to deter inappropriate behaviors, the threat of forced enrollment in a safe driving courses, i.e. PDP courses, and possible license suspensions may further deter or correct these behaviors. This study has shown that 16 and 17 year old drivers received significantly more point accumulation warning letters after the plea ban was implemented. These warnings were given if a GDL driver was convicted of a point-carrying violation. They included a warning that any subsequent point-carrying violations while they were in the GDL program would automatically require their participation in a PDP course. Advisory notices have previously been reported to be effective at reducing violation recidivism (Struckman-Johnson et al., 1989; Jones, 1997; Masten et al., 2004). However, it has also been reported that the effectiveness was age dependant and the recidivism rate for young drivers was much greater than for other age groups (Jones, 1997).

The current study also showed that the number of 17 year-old PDP course attendants was significantly greater in the post-ban era. This is undoubtedly related to the greater number of point-carrying violations for 17 year. The goal of the PDP course was to correct improper or dangerous driving practices (NJMVC, 2010). The extent of the successes of a program of this type is not conclusively known. In general, it has been reported that the number of violations for drivers who complete a driver improvement program is lower than for a control group (Lund et al., 1985; Struckman-Johnson et al., 1989). However, these same reductions have not been shown to translate into subsequent crash reductions as well. It has been proposed that a lack of correlation between crash and violation reductions reflects changes in behaviors for drivers, but that the courses can not change the environmental causative factors that often produce a crash (Struckman-Johnson et al., 1989). If this hypothesis is correct, it would be possible to assume that driver improvement programs succeed in curtailing the negative behaviors of drivers, i.e. fewer violations, but does not succeed in producing safer roads, i.e. fewer crashes. It should be noted that the previous studies examined the effect of these programs on all drivers, not just teen drivers. Interestingly, with regard to teen drivers, the findings of our study suggest that the rate of crashes has also decreased following the plea-agreement ban. However, these results were not shown with statistical significance. Also, it was not possible to determine if the change in crash rate was solely dependant on an increase in interventions or another coincident factor.

Contrary to the increase in point-carrying violations, increases in the number of point accumulation warning letters, and PDP class attendance for 17 year olds, the rate of suspensions for 16 and 17 year old drivers was shown to be significantly less in the post-ban period when compared to the pre-ban period. It is possible that the warning letters and PDP classes were successful in deterring teen drivers from continuing to accumulate violation points on their records. As a result, it may be possible to directly attribute the reduction in suspension orders for teen drivers to the implementation of the plea-agreement ban.

A study performed by Carnegie et al (2009) investigated the effectiveness of the New Jersey's driver improvement methods for reducing crash and violation rates of all drivers. This study was performed prior to the implementation of the plea-agreement ban for GDL drivers and focused on the various intervention methods used in New Jersey including point accumulation notices, driver intervention programs, license suspensions. It was found that the driver improvement methods were generally effective at reducing the crash and violation rates for New Jersey drivers. However, as was the case in previous studies, the effectiveness was considerably less for teen drivers. In fact, teen drivers who had received point notices showed higher violation rates after the intervention. This is contrary to the reductions in violation and crash rates seen for older drivers after receiving a point accumulation notice. However, PDP courses and license suspensions were found to decrease violation and crash recidivism for teen drivers. It should be noted, however, that the Carnegie study did not employ control groups in their study, but rather compared the violation and crash rates of the same drivers before and after a particular intervention was assessed. As a result, it was not possible to determine to what extent any effectiveness metric reductions was simply due to a regression to the mean.

5.4.4 Implications of Results

The results of this study suggest that a ban on plea-agreements for GDL drivers has, in effect, created an environment more in line with the original intentions of the GDL system. Prior to the enactment of the plea ban, teen drivers were frequently bypassing the penalties that had been put in place by pleading to a zero-point carrying violation. This study has shown that removing this loophole has both decreased the number of zero-point violations and increased the number of point-carrying violations for 16 and 17 year old drivers. Also, changes in the assessment of points for teen drivers have resulted in more interventions but fewer suspensions for teen drivers. While the successes of these interventions for teen drivers is still not completely known, at least the New Jersey GDL penalties that are in place are now being enforced as they originally intended. Finally, the ultimate success of the plea-ban may be that the overall number of violations for teen drivers decreased with its enactment, even though the results for 17 year-old drivers were not shown with significance. Nonetheless, this suggests that teen drivers have become more law-abiding and possibly safer while in the GDL program.

5.4.5 Limitations

This study is not without its limitations. The most significant limitation is in the data availability. A longer-term assessment of the GDL violation trends would require more years of data in the post-ban period. However, at the time of this study, newer data was not available. The addition of more post-ban data would undoubtedly provide a more accurate picture from a statistical significance perspective. Furthermore, the restrictions on the date range, i.e. January 1 –

September 17, for each year of data introduces limitations as well. First, it does not account for seasonal changes that may exist in the violation and crash rates for teen drivers. Also, it reduces the statistical power of the results by limiting the number of cases to be included. Finally, an economic recession in the United States began around the same time the plea-agreement ban was enacted. As a result, this may be a confounding factor in the results, particularly if it led to less driving for teens.

Finally, an induced exposure approach was utilized to account for changes in the driving environment for all drivers that are unrelated to GDL implementation. An underlying assumption of this approach is that the ratio of exposure, e.g. vehicle miles traveled, for teen and adult drivers would have remained constant with time. However, it is possible that the travel exposure of teen drivers decreased after GDL implementation as a direct result of the restrictions that were instituted as part of the program. Unfortunately, age-specific VMT was not available for New Jersey drivers so a check of this assumption was not possible.

5.5 Conclusion

The Attorney General of New Jersey instituted a ban on all plea-agreements that reduce a point-carrying violation to a zero point-carrying violation for GDL drivers. The results of this study have shown that this action has led to an environment for GDL drivers whereby their violations will be accounted for as originally intended in the GDL penalty system. It was found that the rate of point-carrying violations increased significantly for 16-17 year old drivers after the ban was enacted, yet the rate of zero-point violations decreased, although not with statistical significance. Furthermore, the increase in point-carrying violations has consequently led to an increase in the number of point accumulation warning notices for 16-17 year olds drivers as well as rate of participation in PDP driver improvement classes. It was also found that the crash rate for teen drivers was lower after the implementation of the plea-agreement ban, although this was not shown with statistical significance. In all, the plea agreement ban has succeeded in effectively instituting the GDL violation penalty system as it was originally intended.

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6. Assessing the Residual Teen Crash Risk Factors after Graduated Drivers License Implementation

6.1 Introduction

An analysis of the Fatal Analysis Reporting System (FARS) shows that, from 2005-2008 there was an average of 4,800 fatalities each year in motor vehicle crashes involving a teen driver. This accounted for 13.3% of all fatalities in motor vehicle crashes, yet teen drivers only accounted for 4.8% of all licensed drivers (FHWA, 2008). Furthermore, motor vehicles continue to be the leading cause of death for all persons aged 13-19 years old, despite an overall decline in teen fatalities over the last two decades (IIHS, 2009). Teen fatalities in motor vehicle crashes (MVCs) are believed to occur for a number of reasons ranging from driver inexperience, inability to deal with distractions, and a propensity for excessive risk taking among some teens.

6.1.1 Graduated Driver's Licensing

Graduated driving licensing laws have been implemented in all 50 U.S. states and the District of Columbia (IIHS, 2010). GDL licensing regulations allow for the gradual accumulation of driving experience for teen drivers through practice in lower risk driving scenarios. These programs often require a period of supervised driving, restrictions on the number of passengers, restrictions on the hours of operation, or any combination of these and other regulations. In 1996, Florida became the first state to implement a modern GDL system in the U.S. (Doherty, 1997; Ulmer, 2000). All other states have updated their licensing laws since this time to include at least some features of a GDL program. However, significant differences exist between each state's licensing laws.

The learner's permit stage is a primary component of many GDL programs and requires increased supervised driving prior to full licensure. Crashes under supervised conditions are relatively infrequent. The learner's permit stage has provided a low crash risk training process for a new driver (Mayhew, 2003). However, when novice drivers graduate from this licensing stage and begin unsupervised driving, their crash risk spikes (Gregersen et al., 2003; Mayhew et al., 2003; McCartt et al., 2003). Any beginning driver, regardless of age or maturity, possesses a higher crash risk than more experienced drivers, particularly within the first few months of unsupervised driving. Both age (i.e. maturity) and experience have been identified as the largest contributors to increased teen crash risk (Williams, 1999; Mayhew, 2003; Mayhew et al., 2003; Simpson, 2003; Waller, 2003; Williams, 2003). Furthermore, excessive risk taking amongst some teens has often been cited as a factor in the increased crash rate (Mayhew et al., 2003).

Efforts to minimize the factors that may increase the likelihood of an unsupervised teen driver crash are an essential component of GDL programs. For instance, the number of passengers in a teen driver vehicle has been shown to be directly correlated to increased crash risk (Chen et al., 2000). As a result, restrictions on the allowed number of passengers for those licensed in the provisional stages has become an integral part of GDL regulation (Williams, 2003). Furthermore, a restriction on nighttime driving has also been shown to effectively reduce teen crashes (Foss et al., 2001; Shope et al., 2004). The inclusion of these regulations is supported by a fundamental pro-GDL argument: crash risk can be reduced by limiting the exposure of the novice driver to more complicated driving scenarios and by limiting driver distractions.

The factors associated with teen driver crash risk are complex, and GDL regulations vary widely from state to state. The technical literature on GDL reflects this complexity and non-standardization. Nonetheless, the majority of studies have shown a net reduction in teen crash rates of 20-30% after the implementation of GDL (Shope et al., 2003; Simpson, 2003; Williams, 2006).

6.1.2 Residual Teen Crash Risk

Much of the research devoted to the study of GDL has focused on the effectiveness of a specific state's regulation for reducing teen crash or fatality risk. Furthermore, studies that explore teen driver risk factors, e.g. night-time driving or driving with passengers, have also been focused on the results within a single state or were conducted prior to GDL implementation. Despite the fact that all states have some form of GDL, teen drivers continue to have higher crash and fatality risks, nationally compared to more experienced drivers. In this study, we hope to identify the factors that continue to contribute to these elevated teen driver crash risks. This may support the argument that teen crashes and fatalities can be further reduced by appropriately enhancing or adding to existing GDL regulations.

6.1.3 Evaluating Pre-Crash Behaviors

Identifying pre-crash events and behaviors of teen drivers is necessary for an assessment of the residual factors that continue to produce an elevated teen crash risk. Previously published methods for collecting the pre-crash information are varied in their approach and data sources.

One method utilizes surveys of teen drivers to obtain crash causation information (Laapotti et al., 2006). However, this information relied on self-reporting and the surveys were often completed long after the event occurred. Other approaches have developed taxonomies to characterize pre-crash events and behaviors in existing datasets to illustrate the circumstances that lead to crash events for all drivers (Najm et al., 2007; Eigen et al., 2009). However, the datasets available at the time of these studies had only limited data on pre-crash behaviors. Hendricks, Fell, and Freedman (1999) developed a crash causation dataset based on the crash investigation and sampling techniques of National Automotive Sampling System Crashworthiness Data System (NASS/CDS), coupled with additional data collection for the causal factors in the crash. While this dataset was not nationally representative, its focus on pre-crash behaviors was able to illustrate the distribution of pre-crash factors in a large number of cases.

More recently, the National Highway Traffic Safety Administration (NHTSA) has released the National Motor Vehicle Crash Causation Survey (NMVCCS) dataset which promises new insights into the circumstances that lead to crashes (Bellis et al., 2008). NMVCCS is a unique crash investigation dataset, which focuses on the circumstances and factors that contribute to a crash. This dataset relies heavily on driver interviews conducted at the scene and on-site evidence collection. This provides a unique opportunity to address some of the issues that have served as limitations in other studies such as timeliness of data collection, limited focus on pre-crash factors, or lacking national representation. This dataset can provide insight into the pre-crash events and behaviors that continue to produce the elevated teen crash risk in the United States, despite GDL implementation.

Objective. Identify the factors that continue to produce an elevated teen driver crash risk after GDL implementation in the United States.

6.2 Methods

This study analyzed the propensity of teen drivers to be involved in crashes that result from certain pre-crash events and behaviors by comparing their crash distributions to adult drivers. For this study, teens were defined as individuals of age 16-18 years old. Adults were defined as individuals of 35-55 years old. The analysis has been restricted to 16-18 year old drivers in crashes, as these are the ages that are most directly affected by GDL. This age range includes those who are driving with a permit, those who are provisionally licensed, as well as those who have recently graduated from the GDL program.

The NMVCCS dataset was analyzed to determine the primary pre-crash circumstances and behaviors that are associated with an elevated teen driver crash risk. NMVCCS is unlike other NHTSA crash datasets because the investigations primarily focused on obtaining evidence and conducting interviews that would explain the causes of the crash. NMVCCS is a nationally representative dataset that includes crashes which occurred from July 3, 2005 to December 31, 2007 between the hours of 6:00am and 11:59pm. Prior to the beginning of the NMVCCS data collection period in 2005, all states and the District of Columbia had implemented at least one component of the modern GDL program with the exception of Wyoming and Montana, which instituted their first GDL regulations in September, 2005 and July, 2006, respectively (IIHS, 2010).

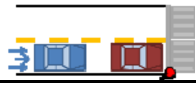
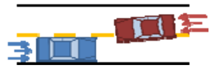
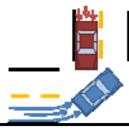
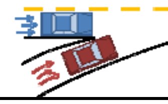
During data collection, NMVCCS relied on special arrangements between crash investigators, EMS, and police agencies as well as constant monitoring of crash occurrences with the aid of police scanners to allow for immediate crash-site investigations and on-site driver interviews. To further ensure the accuracy of the data and inhibit the loss of critical information, it was required that a responding officer was on-scene at the time of the crash investigation and a particular focus was placed on driver interviews. This provided an opportunity to collect evidence and conduct interviews with the involved parties immediately after the crash regarding the pre-crash events and behaviors.

The pre-crash behaviors we analyzed included inappropriate driving (e.g. speeding, weaving), inadequate driving performance (e.g. failure to observe surroundings, following too closely), distractions (e.g. conversations, adjusting radio controls), as well as environmental factors. We also compared crash risk by categorizing pre-crash event scenarios to check the hypothesis that even after GDL implementation, teens might have a heightened crash risk resulting from certain pre-crash events.

A pre-crash classification methodology, unique to this dataset, was developed to identify these crash scenarios. The fundamental basis for this classification method was based on the pre-crash event classification methodology employed by Najm (2007) and Eigen (2009). Their methodology characterized each crash into 1 of 37 pre-crash event scenarios based on the National Automotive Sampling System / Crashworthiness Data System (NASS/CDS) and the National Automotive Sampling System / General Estimates System (NASS/GES). Using a similar approach, we grouped each crash in the NMVCCS database into 1 of the 9 pre-crash event categories shown in Table 21. The category of each crash was based on the number of involved vehicles, the pre-crash events, pre-crash vehicle movement pattern, and accident type. Pre-crash events included lane departures, control loss, or lane encroachment (NMVCCS variable: PREEVENT). Pre-crash vehicle movement patterns included driving straight, decelerating, or turning (NMVCCS variable: PREMOVE). Accident types included driving off the road, rear-end, or forward impact (NMVCCS variable: ACCTYPE).

The distributions of pre-crash behaviors, given as a percentage of all crashes for each age range, were computed to determine the factors that were most frequently present. Risk ratios were computed to determine the pre-crash behaviors and pre-crash event categories that were most frequently associated with teen driver crashes. To identify these factors, the crashes involving teen drivers (16-18 yrs. old) were compared to those involving adult drivers (35-55 yrs. old). This method provided a comparison population (adult drivers) consisting of an age range where the drivers were not subject to the GDL regulations, but were assumed to have been exposed to the same driving environment. Equation 1 shows the method in which risk ratios were calculated.

Table 21. Pre-crash event classification categories

Action/Inaction Resulting in a Rear-End Crash 	**Interaction w/ a Vehicle from in Opposite Direction** 	**Object / Animal / Person in Road** 
Intersection Turning / Cross Paths 	**Event Resulting from Other Vehicle's Actions** 	**Same Direction / Merging** 
Road Departure 	**Control Loss** 	**Other / Unknown** 

Teen and adult crashes “x” represent the number of crashes that occurred with the presence of a given crash factor. Risk ratio values greater than one indicated that the crash factor of interest was represented more frequently in teen driver crashes than adult driver crashes. In other words, a risk ratio of 2 for a specific pre-crash event would indicate that the pre-crash factor of interest was twice as likely to be represented in teen driver crashes as compared to adult driver crashes. Risk ratios were also computed to determine if certain teen driver pre-crash behaviors were seen more frequently in the pre-crash event scenarios for teen drivers relative to those who were not engaged in these behaviors (e.g. the risk of a road departure crash for a distracted teen driver compared to the risk of a road departure crash for a non-distracted teen driver).

$$RR = \frac{\left(\dfrac{Teen\ Crashes\ (x)}{All\ Teen\ Crashes}\right)}{\left(\dfrac{Adult\ Crashes\ (x)}{All\ Adult\ Crashes}\right)} \qquad \textbf{Equation 11}$$

For all calculations, the Taylor series linearization was employed to approximate the variance within the clusters and strata of the dataset sample design. Based on these variance estimations, 95%-tile confidence intervals were computed. Statistical computations were performed with the SAS v9.2 software package using the SURVEYFREQ and SURVEYMEANS procedures (SAS Institute inc., Cary, NC). Finally, it should be noted that the percentages within the crash causation categories in Table 25often sum to more than 100%. Frequently, there is more than one crash causation factor in a crash (e.g. a driver may be talking on the phone and adjusting the radio controls). Therefore, this crash would be counted in both categories.

6.3 Results

For our study, the analyses were based on the characterization of 801 teen (16-18 yr. olds) crashes and 3,159 adult (35-55 yr. olds) crashes extracted from NMVCSS. After application of the national weighting factors, this represents 320,358 teen crashes and 1,179,490 adult crashes.

This section presents a discussion of the risk ratios associated with pre-crash event categories and pre-crash behaviors, and the relationship between the pre-crash behavioral factors and the pre-crash events. Table 25 at the end of this chapter, presents an expanded listing of the distributions of pre-crash events, pre-crash behaviors, environmental factors, and dataset composition.

Table 22. Risk ratios (RR) showing the relative likelihood of a teen driver crash following a pre-crash event, relative to the adult driver crash ratio.

Pre-Crash Classification	**Teen**	**Adult**	**RR (95% CI)**	
Control Loss	8.1%	3.4%	2.40 (1.19-4.85)	*
Road Departure	23.2%	12.4%	1.88 (1.12-3.15)	*
Person / Animal / Object in Road	1.3%	0.8%	1.64 (0.18-15.0)	
Rear-End	13.6%	9.4%	1.44 (0.91-2.27)	
Opposite Direction	3.1%	6.8%	0.39 (0.20-0.74)	*
Event Resulting from Other Vehicle's Actions	2.8%	12.3%	0.23 (0.13-0.42)	*
Same Direction / Merging	3.1%	6.0%	0.52 (0.37-0.74)	*
Intersection Turning / Cross Paths	40.4%	43.8%	0.99 (0.79-1.24)	
Other	3.9%	4.1%	0.39 (0.13-1.15)	

* - Statistically significant result ($\alpha = 0.05$).

Table 23. Risk ratios (RR) showing the relative likelihood of a teen driver crash following a pre-crash behavior, relative to the adult driver crash ratio.

Pre-Crash Behaviors	Teen	Adult	RR (95% CI)	
Distracted Driver Crashes	34.4%	19.9%	1.73 (1.25-2.38)	*
Conversing	18.0%	9.4%	1.91 (1.41-2.59)	*
Other Distraction	13.1%	5.3%	2.48 (1.20-5.12)	*
Exterior Factor	11.1%	7.3%	1.53 (0.94-2.49)	
Inappropriate Driving	24.1%	13.1%	1.83 (1.38-2.43)	*
Illegal Maneuver	8.1%	7.9%	0.93 (0.40-2.12)	
Aggressive Act	10.6%	3.4%	3.42 (1.17-7.09)	*
In a Hurry	7.6%	3.9%	1.94 (1.03-3.65)	*
Inadequate Awareness	50.3%	34.1%	1.47 (1.30-1.67)	*
Passenger Distraction	16.6%	8.3%	2.00 (1.51-2.64)	*
Distraction in the Vehicle	25.3%	11.4%	2.08 (1.52-2.84)	*
At Least One Passenger	38.5%	26.3%	1.46 (1.18-1.81)	*
BAC (>0.01)	0.7%	4.1%	0.16 (0.03-0.84)	*

* - Statistically significant result ($\alpha = 0.05$).

Table 24. Risk ratios of a pre-crash event for teen drivers engaged in pre-crash behaviors relative to teens not engaged in the particular driving behavior.

	Distractions			Inappropriate Driving		
Pre-Crash Classification	**Present**	**Not Present**	**RR** (95% CI)	**Present**	**Not Present**	**RR** (95% CI)
Control Loss	**5.2%**	**9.6%**	**0.55** (0.20-1.49)	**8.6%**	**7.9%**	**1.08** (0.51-2.29)
Road Departure	**32.4%**	**18.4%**	**1.76** (1.23-2.52) *	**35.3%**	**19.4%**	**1.87** (1.32-2.50) *
Pedestrian / Cyclist / Animal / Object in Road	**2.4%**	**0.7%**	**3.29** (1.74-6.25) *	**0.1%**	**1.7%**	**0.03** (0.00-0.52) *
Rear-End	**16.9%**	**11.8%**	**1.43** (0.53-3.88)	**7.3%**	**15.5%**	**0.47** (0.20-1.11)
Opposite Direction	**2.8%**	**3.2%**	**0.88** (0.19-4.12)	**6.1%**	**2.1%**	**2.96** (0.66-13.2)
Event Resulting from Another Vehicle's Actions	**3.2%**	**2.7%**	**1.18** (0.54-2.61)	**0.2%**	**3.7%**	**0.05** (0.00-0.69) *
Same Direction / Merging	**3.6%**	**2.9%**	**1.24** (0.29-5.25)	**5.8%**	**2.3%**	**2.54** (0.86-7.47)
Intersection Turning / Cross Paths	**32.9%**	**48.6%**	**0.68** (0.52-0.88) *	**35.9%**	**45.5%**	**0.79** (0.41-1.51)
Other	**0.6%**	**2.1%**	**0.31** (0.08-1.23)	**0.8%**	**1.9%**	**0.43** (0.18-1.03)

	Passengers			Inadequate Awareness		
Pre-Crash Classification	**Present**	**Not Present**	**RR** (95% CI)	**Present**	**Not Present**	**RR** (95% CI)
Control Loss	**12.0%**	**5.6%**	**2.13** (1.08-4.20) *	**0.6%**	**15.6%**	**0.04** (0.01-0.22) *
Road Departure	**21.3%**	**24.5%**	**0.87** (0.60-1.25)	**6.6%**	**40.1%**	**0.17** (0.12-0.24) *
Person / Animal / Object in Road	**0.4%**	**1.9%**	**0.20** (0.01-4.17)	**0.1%**	**2.5%**	**0.04** (0.00-0.71) *
Rear-End	**11.3%**	**15.0%**	**0.75** (0.39-1.45)	**21.2%**	**5.8%**	**3.67** (1.53-8.83) *
Opposite Direction	**2.7%**	**3.3%**	**0.82** (0.28-2.42)	**1.0%**	**5.2%**	**0.18** (0.05-0.76) *
Other Vehicle's Actions	**3.8%**	**2.2%**	**1.68** (0.69-4.09)	**1.2%**	**5.6%**	**0.02** (0.00-0.15) *
Same Direction / Merging	**3.4%**	**2.9%**	**1.17** (0.28-4.95)	**3.2%**	**3.0%**	**1.07** (0.40-2.87)
Intersection Turning / Cross Paths	**43.7%**	**42.9%**	**1.02** (0.82-1.26)	**66.7%**	**19.4%**	**3.43** (2.31-5.17) *
Other	**1.5%**	**1.7%**	**0.90** (0.37-2.16)	**0.4%**	**2.8%**	**0.14** (0.03-0.60) *

Table 2 shows that, when compared to adult drivers, teen drivers who were in a crash were roughly two and a half times as likely to be in a crashes resulting from control loss and almost twice as likely to be in a crash resulting from a road departure. Table 23 shows that distractions were 1.7 times more likely to be present in a teen driver crash as compared to an adult driver crash. The risk of a crash when driving with a passenger was shown to be about one and a half times greater for teen drivers as compared to adults. The five factors most frequently associated with teen driver crashes in which the teen was distracted, driving inappropriately, or inadequately aware of their driving environment are given in Figure 30. The values express the representation of each factor within each behavioral category. For example, passenger distractions were present in 48% of all distracted teen driver crashes. Specific crash causation factors were combined to create the crash factors listed. For example, passenger distractions combined conversing with a passenger or looking at a passenger in the vehicle. Internal and external distractions included any object or person that had the attention of the driver prior to the crash. Phone use included dialing or talking on a phone while driving. Illegal turns included turning from the wrong lane or illegal U-turns. Proceeding without awareness includes turning while visibility is limited or proceeding without enough vehicle clearance.

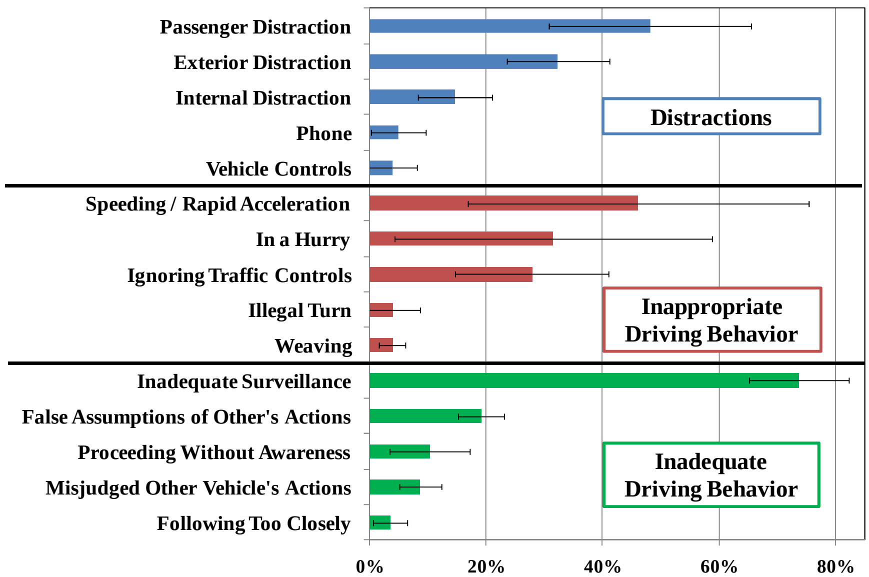


Figure 30. Top five crash factors given as the percentage of all distracted driver crashes, inappropriate driving crashes, and inadequate awareness crashes for teen drivers.

Inappropriate driving was 1.8 times more likely to have been a factor in a teen driver crash when compared to adults. This included a significant increase in crash risk from aggressive acts and being in a hurry. Speeding, rapid acceleration, and being in a hurry were the most frequently cited behaviors for teens who crashed while driving inappropriately. Also, inadequate awareness was one and a half times more likely to be a factor in teen driver crashes as compared to adult drivers. Inadequate surveillance was by far the most prevalent factor in crashes that involved inadequate driving behaviors in teen driver crashes.

As shown in Table 24, in teen driver crashes where inadequate driving awareness was cited, the risk of a rear-end crashes was almost four times as high as compared to teen driver crashes where this was not listed as a factor. Furthermore, inappropriate driving behavior resulted in almost twice the likelihood of a control loss crash as compared to teen driver crashes where this factor was not reported. Teen driver crashes with pre-crash distractions were 1.76 times more likely to result from road departures than for those without a pre-crash distraction and over three times as likely to result from an obstruction in the road. Interestingly, teen driver crashes with passengers were twice as likely to have resulted from a control loss as compared to teen drivers without passengers.

6.4 Discussion

This study has identified events and behaviors that are represented more frequently in teen driver crashes, relative to adult driver crashes. The study has shown that teen drivers continue to be deficient in their driving awareness and abilities, relative to adult drivers, despite the inclusion of GDL components in every state's licensing process. Many studies published prior to GDL implementation presented these same, teen-specific factors as the root causes for increased teen crash and fatality risk. Often these studies were performed with the stated goal of encouraging reform in the licensing procedures, which led to the acceptance of GDL programs in the United States. In the years that followed, a number of individual state GDL programs have been analyzed to determine their effectiveness for reducing teen crash and fatality rates. However, to date, the existing research does not provide a national perspective on remaining teen crash causation factors. This is the first national study to focus on the residual factors that continue to lead to a higher teen crash risk after GDL implementation.

6.4.1 Teen Driver Crash Risk

Teen driver crashes were more likely to result from a control loss and road departure event as compared to adults. Teens who were in a crash were also more likely to be distracted, driving inappropriately, or inadequately aware of their environment when compared to adult drivers. These characteristics reflect the lack of experience and propensity of teen drivers to engage in risky behaviors. These same characteristics were often considered as a source of the elevated teen driver crash risk prior to GDL implementation (Williams et al., 1995; Laapotti et al., 1998; McKnight et al., 2003; McCartt et al., 2009).

Pre-Crash Event

By far, the pre-crash event category that produced the largest number (43.2%) of teen driver crashes after GDL implementation was intersections or turning vehicles. Similarly, this was also the largest pre-crash category for adult crashes (43.8%). In contrast, 44.9% of all teen driver crashes were categorized as road departure, rear-end, or control loss crashes as compared to only 25.2% of adult crashes. Teen drivers were 2.40 (CI:1.19-4.85) times more likely to be in a crash resulting from control loss, 1.88 (CI:1.12-3.15) times more likely to be in a crash resulting from a road departure, and a statistically insignificant 1.44 (CI: 0.91-2.27) times more likely to be in a rear-end crashes when compared to adult driver crashes. Each of these pre-crash events likely resulted from a lack of driving experience or lack of awareness of the road environment. Furthermore, the increased risk of road departure and control loss crashes most likely contributed to teen driver crashes being 1.64 (1.18-2.28) times more likely to be a single vehicle crash. Williams (1995) showed that teen drivers were also more susceptible to single-vehicle crashes, prior to GDL. Furthermore, it has been suggested that this propensity reflects the risk taking and inexperience of teen drivers (Williams, 2006).

Inappropriate Driving Behavior

Inappropriate driving behavior and inadequate driving awareness had previously been shown to be a factor in teen crashes more often than for adults before GDL implementation (Williams et al., 1995). Additional pre-GDL research has indicated that these deficiencies result from the inability of the teen driver to sense when they are following too close, when they are traveling too fast, or how to recover if they drift off the road resulting in the increased crash risk for these categories (Dingus et al., 1997; Laapotti et al., 1998; Williams, 2006). Similarly, the results from our study shows that road departure crashes were 1.87 (CI: 1.32-2.50) times more likely in teen driver crashes with inappropriate driving as compared to those without. Inappropriate behavior includes aggressive driving, speeding, or frequently changing lanes. Laapotti and Keskinen (1998) found that young Finnish drivers had an increased risk of control loss crashes, which often lead to road departures, when driving inappropriately. Furthermore, it was noted that these inappropriate driving behaviors magnified the lack of experience when the teen driver was presented with a possible crash scenario. Thus, the teen driver's lack of experience combined with inappropriate driving behavior would further increase their crash risk. This type of behavior has often been linked to the thrill-seeking mentality of teen drivers (McKnight et al., 2003; Williams, 2006). The reason that teens engage in these behaviors has been attributed to a number of factors including peer-pressure, the way that teens prioritize risk, and as a normal function of adolescence (Spear, 2000; Keating et al., 2008). Whatever the reason, our research shows that inappropriate driving was 1.83 (CI: 1.38-2.43) times as likely to be represented in teen driver crashes as compared to adults, indicating that these behaviors still play a significant role in teen driver crash risk after GDL implementation.

Inadequate Driving Awareness

Prior to GDL implementation, inadequate driving awareness was often cited as a common crash causation factor for teen drivers (Williams et al., 1995; Williams, 2006). Braitman et al (2008) found that inadequate evaluation, search, and detection performance contributed to a majority of 16-year old crashes in Connecticut. In our study, inadequate surveillance was present in 74% of teen crashes where the driver was inadequately aware of their driving environment. McKnight (2003) showed that younger and less experienced teen drivers in California and Maryland had a higher crash risk when compared to older teen drivers due to lack of visual search, not watching the car ahead, driving too fast for conditions, and failure to adjust to wet roads. As shown in this study, despite GDL licensing procedures nationwide, inadequate driving awareness was still represented in 50.3% of teen driver crashes. Inadequate driving awareness was cited 1.47 (1.30-1.67) times more often in teen driver crashes as compared to adults. We also found that rear-end crashes were 3.67(CI: 1.53-8.83) times as likely to be represented in teen crashes where the driver was inadequately aware as compared to those who were not. These results indicate that driving awareness factors continue to play significant roles in teen driver crash risk after GDL.

Driver Distraction

Distractions also contributed to a significantly greater crash risk for teen drivers. In our dataset, distractions were considered a factor in 34.4% of teen crashes as compared to 19.9% of adult crashes. Of these, conversations with passengers were cited in 16% of teen crashes and represented 91% of all teen driver conversations prior to a crash event.

Cell phone use

In the NMVCSS dataset, cell phone use while driving for teen drivers played a surprisingly small role in crashes, representing less than 2% of teen driver crashes. Texting was not cited in any of our teen driver cases. Similar results were reported in a study of Connecticut 16-year olds which found that 26% of drivers were distracted prior to a crash and that 2% of the distractions were from a cell phone conversation (Braitman et al., 2008). It is possible that the low number of cell phone conversations and lack of texting crashes reflects the effectiveness of mandates included in many GDL programs that seek to curb teen cell phone use while driving. However, the infrequency of cell phone use in this study may also reflect the frequency of cell phone use during the NMVCSS data collection period. Cell phone use and, to a greater extent, texting while driving has increased significantly since 2007 (Madden et al., 2009).

Driver cell phone use is widely believed to increase crash risk. The Insurance Institute for Highway Safety (2005) estimates that cell phone use can increase the risk of an injurious crash by as much as 400%. Teens are at an especially high risk for crashes while using a cell phone which has led to the introduction of cell phone restriction for novice drivers in 25 states and Washington, D.C. as of May, 2010 (IIHS, 2010).

Passengers

In this study, the most significant distraction for teen drivers was the presence of passengers. In teen driver crashes, the presence of a passenger was represented 1.46 (CI: 1.18-1.81) times more often than for adult drivers. As shown by Farrow (1987), there is a strong association between the presence of peers and inappropriate driving behaviors for teen drivers. Therefore, the combination of a lack of experience along with the distractions and inappropriate driving behaviors associated with passengers presents a troublesome combination of risk factors for teen drivers. This type of association is the reason that many states have imposed restrictions on the number of passengers or the familial relationship of passengers for teen drivers. At the time NMVCCS data collection began (7/3/2005), 29 states had implemented restrictions on passengers for teen drivers and another 11 instituted passenger restrictions during the data collection period (7/3/2005-12/31-2007) (IIHS, 2010). Nonetheless, passenger distractions (i.e. talking to or looking at a passenger) were present in 20% of teen crashes compared to 9% of adult crashes, resulting in significantly greater crash risk ratio associated with the presence of passengers in teen driver vehicles. Furthermore, control loss crashes were represented 2.13 times more frequently in teen driver crashes with passengers as compared to those without. These results suggest that current practices that limit the number of passengers or the familial relationship of passengers for teen drivers may not be sufficient in the early stages of licensure.

Alcohol

Alcohol is often cited as a significant factor in teen driver crashes. Our study found that alcohol was a significantly less frequent factor in teen crashes than in adult crashes. However, this is a result of the infrequency of drinking and driving for teens, relative to adults, and less of a reflection on the risk of a crash for those who do drink and drive. In fact, Mayhew (1986) found that teen drivers drink and drive less frequently than adults but have higher crash risk when they do. Also, the NMVCCS dataset did not include crashes that occurred between midnight and 6am. Teens that drink and drive may do so at night. These teens would not be included in this analysis.

Night Driving

Nighttime driving has been identified as a high-risk driving scenario for teen drivers, resulting in an increased crash risk and fatality risk (Williams et al., 1995; Doherty, 1997; Williams, 2003). As a result, most states have instituted restrictions on the hours that GDL drivers can be on the road. However, the NMVCCS database only included crashes that occurred between 6:00am – 11:59pm. As a result, an evaluation of the crash risk associated with nighttime driving for teens was not possible in this study.

6.4.2 Implication of Results

Many of the factors and pre-crash categories that have been associated with an increase in teen driver crash risk are highly dependent on driver experience and awareness, namely road departure and control loss crashes. Deery (1999) reported that teen drivers are quite adept at acquiring basic driving skills. However, their limited experience does not allow them to develop the high-order cognitive abilities required to safely address many complex driving situations.

Furthermore, Brown and Groeger (1988) reported that risk perception is controlled by two inputs: 1) information on the potential hazards and 2) information on a person's abilities to handle these hazards. A recent study examined the driving abilities of Finnish and Dutch novice drivers and found that 30-40% of novice drivers over estimate their own driving abilities (Mynttinen et al., 2009).

One interpretation of our findings is that GDL has reduced teen crashes by limiting exposure rather than by providing the appropriate training for teens. Fohr et al (2005) suggests the real effectiveness of GDL may be in its ability to limit exposure to risky driving situations while subject to the regulations; Fohr et al suggested that GDL does not necessarily produce safer or more capable drivers. Our study has shown that despite the structured training and driving practice provided by GDL, the inability of many teens to assess the presence of potential hazards and the inability to adequately assess their own driving capabilities continues to be a source of increased crash risk. However, because NMVCSS collected only post-GDL data, our study should not be interpreted as providing a definitive answer to this question. One possible explanation for our findings, for example, would be that GDL has been very effective for most teens, but has been ineffective for some teen sub-groups because of learning differences. We hope that the worrisome findings of our study will motivate a follow-up investigation of this very important question using an alternative dataset.

Our study has shown that many of the experience and skill related factors which led to pre-GDL crashes continue to contribute to an increased crash risk for teen drivers, despite a reduction in crash rate after GDL implementation. As highlighted by Ferguson (2003), GDL has components that at least partially address these crash factors that disproportionately lead to an increased teen crash risk. However, there are enhancements that can be explored to address more of the inexperience and maturity problems that continue to play significant roles in the elevated teen crash risk. These include increased penalties resulting from the most frequent inappropriate driving behaviors such as speeding.

Another enhancement would be secondary driving classes that teach risk awareness and vehicle control after the basic driving skills have been mastered. In particular these programs should focus on the most common inadequate driving behaviors such as inadequate surveillance and judging the actions of other vehicles. Also, these programs could stress the consequences of inappropriate driving behavior, specifically the factors that are shown in this study to be particularly detrimental for teen drivers, such as the increased risk of road departure crashes. Secondary training programs have been implemented in GDL programs abroad. However, the successes of these enhancements are unclear and require further study before they are incorporated into GDL regulation in the United States (Ferguson, 2003).

It is possible that an increase in the minimum number of logged hours in the supervised driving stage of licensure would provide more contextual experience for the teen driver and may reduce the influence of these factors. Before the NMVCSS data collection period (7/3/2005), 37 states had requirements for a minimum number of supervised driving hours, During the NMVCSS data collection period, another five states instituted minimum practice requirements. However, the minimum requirements by state ranged from 12-100 hours. Furthermore, five of the states allowed exemptions from this rule if the driver had taken a driver's training course (IIHS, 2010). These exceptions were allowed despite evidence that discounting the supervised driving requirements with the successful completion of a driver's training course does not make up for the safety benefits of supervised driving (Mayhew et al., 1998).

Finally passenger distractions continue to be a significant factor in teen driver crashes. States should continue to limit the presence of passengers to reduce these effects, and should strongly consider a ban on all passengers traveling with GDL drivers. Prior to the data collection period for this dataset, seven (7) states and Washington, D.C. had banned passengers (with the exception of parents) for provisionally licensed drivers for at least the first 90 days of licensure. While these same districts have since updated these policies, no other state has instituted a similar ban on passengers (IIHS, 2010).

6.4.3 Significance Reporting and Table Structure

In many instances the relative risks comparing the risk of teen drivers being involved in a particular crash type or resulting from a particular driving situation may express a significant result (i.e. the confidence intervals do not include a value of one) when normalized to adult drivers, but a similar comparison of crash mode percentages shown in Table 25 for teen and adult drivers have over-lapping confidence intervals, suggesting an insignificant result. This is the result of the different methods used to compute the confidence intervals. The confidence intervals for the relative risk estimates reflect the variances within the strata for all cases included in the analysis (i.e. teen and adult drivers) while the confidence intervals for the proportions (i.e. percentages) use the variance within the strata for each sub-population (i.e. teen or adult drivers only). However, as a result of the differences in the confidence interval determination methods, slightly different conclusions can be drawn from each. The relative risk confidence intervals evaluate how well the point estimate reflects the actual risk of a teen driver crash when normalized to adult driver crashes. On the other hand, the confidence intervals from the proportions express the relative frequency of a particular crash situation or behavior, but only within a given sub-population.

6.4.4 Limitations

This research has presented a data-driven assessment of some of the remaining crash causation behaviors and scenarios that continue to contribute to a greater crash risk for teen drivers after GDL implementation. This is not meant, however, to discount the findings of other studies that have noted significant reductions in teen driver crash rates associated with GDL implementation. Instead, it is a reminder that teen drivers have different abilities and susceptibilities, when compared to more experienced drivers. Furthermore, this study highlights the need for continuing adjustment and enhancement of current GDL regulation. Specifically, it is possible that current GDL laws are less effective at addressing the experience issues that continue to lead to teen crashes as well as the influence of distractions, namely passengers, on teen driver crash risk.

The definition of "teen drivers" as those who are 16-18 years old is meant to focus on the drivers who are most directly influenced by GDL regulation. In most states, GDL regulation covers 16-

17 year old novice drivers and can extend into the 18 year old population as well. However, the "teen" group will include some drivers who are not under GDL regulation, but have most likely graduated from a GDL program. Ideally, it would be beneficial to perform an age-specific analysis to determine general trends as they relate to age. However, there were insufficient cases to conduct this analysis. Similarly, licensure date and licensing status were not available in the NMVCCS dataset. As a result, it was not possible to perform an analysis based on license type, i.e. learner's permit, provisional license, or basic license.

Another limitation is that this national study aggregates all cases from NMVCCS regardless of the state in which the crash occurred. GDL regulations can vary significantly by state. Based on the NMVCCS survey structure, cases for this dataset were selected from many, but not all states. This may affect the distributions expressed in the results. However, the primary sampling units for the NMVCCS dataset are provided in the coding manual, making it possible to know the states from which data was collected (Bellis et al., 2008). Of the 17 states sampled to create the NMVCCS dataset, it was found that the distributions of regulations were similar to what were seen nationally at the time of data collection. Of the 17 states, 11 had passenger restrictions prior to data collection, 2 instituted them during data collection and 4 had none during this time period. Similarly, 14 states implemented nighttime driving restriction prior to data collection, 1 instituted them during data collection and 2 had none during this time period. Finally, 13 had a minimum requirement for the number of logged hours in permit license stage prior to data collection and 4 had none during this time period. However, 3 of the states waived the requirement if the teen driver completed a driver training course. In all, the logged hour requirements for the 17 states ranged from 20-60 hours (IIHS, 2010).

The NMVCCS dataset does not contain crashes that occurred between 12-6am. This also serves as a limitation. Based on an analysis of the FARS database over the same time period, it was found that 21% of all fatalities involving teen drivers occurred between these hours. Therefore, our study is missing significant information regarding the behaviors and events that lead to teen driver crashes at night - a time when teens are known to have an even higher crash risk.

Finally, the method for computing risk ratios assumes that teen and adult drivers were exposed to the same driving environment. However, systemic biases could have existed that would have resulted from differences in the teen and adult driving populations. These biases may be directly related to the age range that was used to define the adult age group. For example, adults may drive later model vehicles with advanced countermeasures, e.g. electronic stability control which would result in fewer road departure crashes. Other biases may result from different vehicle maintenance priorities or roadway travel differences between teens and adults. In the context of the current study, our methods were utilized with assumptions. These include 1) the crash rates of teen and adult drivers are independent and 2) any underlying systemic biases are negligible.

6.5 Conclusion

Despite marked reductions in the number of teen crashes after the implementation of GDL, teen drivers are still susceptible to higher crash rates resulting from specific behaviors and pre-crash scenarios. However, the identification of these teen driver crash causation factors may serve to guide future enhancements to current GDL regulations. Overall, the results show that 1) intra-vehicle distractions, namely passengers, 2) inappropriate and inadequate driving, 3) control loss, and 4) road departures continue to create a greater teen crash risk when compared to adult driver crashes after GDL implementation. Based on the findings of this study, it is recommended that the states consider a ban on passengers in the first months of unsupervised driving. Also, this study has shown evidence to motivate further investigation into the benefits of secondary driving courses. These courses could supplement current GDL regulation with training that addresses the pre-crash events and behaviors that are outlined in this study and help to produce a more adept teen driver population in the United States.

6.6 References

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Table 25. Distribution of Pre-Crash Classifications Crash Causation Factors for Teen and Adult Drivers (NMVCCS 2005-2007).

	TEEN				ADULT			
	% (95% CI)		**n**	**n (w'td)**	**% (95% CI)**		**n**	**n (w'td)**
Total Sample Size			**801**	**320,358**			**3,159**	**1,179,490**
Pre-Crash Classification								
Other	**1.6%**	(3.0%-5.3%)	23	5,120	**4.1%**	(3.0%-5.3%)	161	48,713
Control Loss	**8.1%**	(11.4%-29.5%)	50	25,923	**3.4%**	(2.4%-4.3%)	81	39,716
Road Departure	**23.2%**	(0.0%-2.2%)	152	74,438	**12.4%**	(9.7%-15.0%)	343	145,740
Pedestrian / Cyclist / Animal / Object in Road	**1.3%**	(12.0%-15.9%)	6	4,184	**0.8%**	(0.2%-1.4%)	28	9,394
Rear-End	**13.6%**	(2.1%-5.6%)	89	43,426	**9.4%**	(7.2%-11.6%)	319	111,184
Opposite Direction	**3.1%**	(3.1%-5.5%)	26	9,777	**7.9%**	(6.8%-8.9%)	170	92,592
Event Resulting from Another Vehicle's Actions	**2.8%**	(1.9%-5.2%)	40	9,084	**12.3%**	(10.6%-14.1%)	362	145,471
Same Direction / Merging	**3.1%**	(31.1%-49.6%)	33	9,977	**6.0%**	(4.1%-7.8%)	216	70,296
Intersection Turning / Cross Paths	**43.2%**	(2.3%-5.6%)	382	138,430	**43.8%**	(38.5%-49.1%)	1,479	516,384
Crash Causation Factors								
Distracted Driver Crashes	**34.4%**	(25.5%-43.3%)	282	110,046	**19.9 %**	(16.6%-23.2%)	687	234,624
Conversing	**18.0%**	(13.2%-22.7%)	**162**	**57,503**	**9.4%**	(6.6%-12.2%)	**344**	**110,932**
Conversing with passenger	**91.0%**	(83.3%-98.7%)	144	52,334	**82.9%**	(72.6%-93.3%)	289	92,008
Talking on phone	**9.0%**	(1.3%-16.7%)	18	5,169	**14.1%**	(5.3%-22.8%)	51	15,599
Talking on CB radio	**0.0%**	(0.0%-0.0%)	0	0	**0.6%**	(0.0%-1.7%)	1	611
Other	**0.1%**	(0.0%-0.1%)	0	0	**2.5%**	(0.0%-7.2%)	3	2,713
Other Distraction	**13.1%**	(3.6%-22.7%)	**81**	**42,109**	**5.3%**	(3.5%-7.1%)	**176**	**62,460**
Looking at Other Occ	**29.9%**	(24.8%-34.9%)	21	12,585	**19.4%**	(3.9%-34.9%)	27	12,139
Dialing Phone	**1.2%**	(0.0%-3.4%)	3	513	**4.9%**	(0.0%-11.0%)	12	3,076
Adjusting Radio	**8.5%**	(0.0%-21.4%)	14	3,585	**2.9%**	(0.0%-6.5%)	7	1,815
Adjusting Vehicle Controls	**1.7%**	(0.0%-3.7%)	4	695	**2.1%**	(0.0%-4.8%)	4	1,283
Retrieving Object	**19.7%**	(13.7%-25.7%)	17	8,285	**18.3%**	(11.0%-25.6%)	37	11,442
Eating / Drinking	**13.0%**	(0.3%-25.6%)	7	5,472	**13.1%**	(3.6%-22.7%)	24	8,203
Smoking	**5.6%**	(0.0%-13.6%)	2	2,350	**6.3%**	(0.1%-12.5%)	11	3,940
Reading Map/Directions/Newspaper	**0.0%**	(0.0%-0.0%)	0	0	**6.3%**	(1.1%-11.4%)	14	3,920
Focused on Internal Object	**27.8%**	(17.4%-38.3%)	17	11,720	**26.3%**	(17.8%-34.8%)	39	16,413
Texting	**0.0%**	(0.0%-0.0%)	0	0	**0.4%**	(0.0%-1.1%)	1	228
Exterior Factor	**11.1%**	(6.7%-15.6%)	**93**	**35,579**	**7.28%**	(5.1%-9.5%)	**257**	**85,855**
Looking at Crash	**0.6%**	(0.0%-1.8%)	1	203	**1.9%**	(0.0%-5.0%)	4	1,666
Looking at Traffic	**35.7%**	(8.7%-62.7%)	58	12,699	**48.0%**	(38.8%-57.1%)	149	41,169
Looking for Address	**2.8%**	(0.0%-6.9%)	4	1,000	**2.8%**	(0.0%-5.7%)	8	2,361
Looking at Outside Person	**1.7%**	(0.0%-4.0%)	3	607	**11.7%**	(0.0%-23.6%)	23	10,041
Looking at Building	**3.9%**	(0.0%-11.9%)	3	1,371	**5.7%**	(0.1%-11.3%)	13	4,899
Unspecified Outside Focus	**32.7%**	(2.2%-63.2%)	10	11,630	**14.8%**	(3.8%-25.9%)	16	12,744
Other	**15.9%**	(5.7%-26.0%)	13	5,644	**12.3%**	(5.3%-19.3%)	37	10,548
Looking At Animal	**7.0%**	(0.0%-20.2%)	2	2,479	**2.8%**	(0.2%-5.5%)	7	2,427

Inappropriate Driving Behavior	**24.1%**	(19.7%-28.5%)	179	77,112	**13.1%**	(10.5%-15.8%)	479	154,855
Illegal Maneuver	**8.1%**	(3.8%-10.2%)	**146**	**47,746**	**7.9%**	(5.6%-12.4%)	**287**	**93,130**
Crossed Full Barrier Lines While Passing	**4.9%**	(0.0%-10.2%)	5	1,144	**5.3%**	(0.0%-11.5%)	4	4,936
Passed On Right	**0.0%**	(0.0%-0.0%)	0	0	**1.0%**	(0.0%-2.8%)	4	963
Turned From Wrong Lane	**9.6%**	(0.0%-24.1%)	4	2,248	**1.6%**	(0.4%-2.7%)	12	1,458
Initiated Illegal U-Turn	**3.6%**	(1.1%-6.1%)	3	846	**2.4%**	(0.5%-4.2%)	13	2,192
Failed To Obey Traffic Control Device	**77.3%**	(65.4%-89.3%)	65	18,119	**78.1%**	(69.0%-87.1%)	222	72,706
Drove Wrong Way On Roadway	**5.5%**	(0.0%-13.0%)	3	1,292	**1.1 %**	(0.0%-2.3%)	7	993
Other Illegal Maneuver	**1.9%**	(0.0%-4.3%)	3	444	**10.6%**	(5.0%-19.3%)	25	9,882
Aggressive Act	**10.6%**	(3.7%-17.5%)	**137**	**62,714**	**3.42%**	(2.0%-4.9%)	**119**	**40,392**
Speeding	**83.1%**	(70.3%-96.0%)	65	31,233	**55.6%**	(29.1%-82.0%)	49	22,438
Tailgating	**1.2%**	(0.0%-3.6%)	3	457	**0.6%**	(0.1%-1.1%)	3	246
Rapid/Frequent Lane Changes/Weaving	**8.0%**	(1.3%-14.6%)	15	2,993	**20.2%**	(0.0%-41.1%)	24	8,165
Ignoring Traffic Control Devices	**9.2%**	(0.0%-22.8%)	11	3,454	**13.7%**	(4.6%-22.9%)	27	5,536
Accelerating Rapidly From Stop	**12.5%**	(0.4%-24.6%)	6	4,705	**0.8%**	(0.0%-2.2%)	4	317
Stopping Suddenly	**0.0%**	(0.0%-0.0%)	0	0	**0.2%**	(0.0%-0.5%)	1	65
Honking Horn	**0.0%**	(0.0%-0.0%)	0	0	**0.4%**	(0.0%-1.3%)	1	151
Flashing Lights	**0.0%**	(0.0%-0.0%)	0	0	**0.8%**	(0.4%-1.3%)	1	337
Obscene Gestures	**0.0%**	(0.0%-0.0%)	0	0	**0.4%**	(0.0%-1.3%)	1	167
Obstructing The Paths Of Others	**0.0%**	(0.0%-0.0%)	0	0	**0.5%**	(0.0%-1.7%)	1	210
Other	**1.6%**	(0.0%-4.4%)	5	608	**6.8%**	(0.0%-13.8%)	7	2,761
In a Hurry	**7.6%**	(1.6%-13.6%)	**58**	**24,293**	**3.9%**	(2.9%-4.9%)	**153**	**46,189**
Inadequate Awareness	**50.3%**	(46.1%-54.9%)	415	161,284	**34.1%**	(30.7%-37.6%)	1,248	402,720
Inadequate Surveillance	**73.7%**	(65.1%-82.3%)	275	118,905	**40.7%**	(33.6%-47.7%)	487	163,755
Other Driver Recognition Factors	**16.0%**	(8.5%-23.5%)	62	25,807	**6.0%**	(3.3%-8.6%)	69	23,999
Following Too Closely	**3.6%**	(0.7%-6.5%)	26	5,750	**5.5%**	(2.8%-8.1%)	63	21,965
Misjudged Vehicles Direction Of Approach	**8.7%**	(5.1%-12.3%)	46	14,025	**5.7%**	(4.0%-7.5%)	82	23,088
False Assumption Of Other Road User's Actions	**19.2%**	(15.2%-23.1%)	97	30,899	**24.3%**	(19.2%-29.5%)	322	98,088
Other Driver Decision Factor	**17.7%**	(12.5%-22.9%)	61	28,521	**17.8%**	(13.5%-22.1%)	225	71,824
Other Factors and Distributions								
Passenger Distraction	**16.6%**	(12.1%-21.0%)	145	53,029	**8.3%**	(6.7%-9.9%)	292	97,811
At Least One Passenger	**38.5%**	(29.2%-47.7%)	340	123,303	**26.3%**	(23.4%-29.1%)	935	310,089
Single Vehicle Crash	**18.7%**	(11.3%-26.0%)	117	59,752	**11.4%**	(8.8%-14.0%)	298	134,399
Weather	**10.1%**	(5.5%-14.6%)	87	32,208	**10.9%**	(8.5%-29.1%)	291	128,224
BAC (>0.01)	**0.7%**	(0.0%-1.7%)	4	2,122	**4.1%**	(2.4%-5.8%)	106	7,490
Speed Limit (km/h)	**65.9**	(62.5-69.3)	780	315,817	**68.9**	(64.4-72.4)	3,064	1,153,890
Gender (% Male)	**51.5%**	(45.8%-57.3%)	801	320,358	**57.5%**	(51.4%-63.6%)	3,159	1,179,491
Vehicle Type (% Car)	**66.9%**	(60.9%-72.8%)	801	320,358	**43.5%**	(40.3%-46.7%)	3,159	1,179,491

7. The Effectiveness of GDL when Accounting for Exposure Reductions for Teen Drivers in United States

7.1 Introduction

Graduated driver's licensing (GDL) was implemented throughout the United States to gradually increase teen driver exposure to more complicated driving scenarios through regulation. The ultimate objective was to reduce the teen driver crash and fatality rate, which is known to be significantly higher for young drivers when compared to older drivers (Williams et al., 1995).

7.1.1 The GDL experience in the United States

Teen-specific behaviors that are considered the source of the elevated teen driver crash risk are directly targeted in GDL regulation (Williams, 2003). The largest factor is a general lack of driving experience. Novice drivers, regardless of age, have a much higher crash risk than more experienced drivers (Mayhew et al., 2003). This has lead to the inclusion of a supervised driving stage in the GDL licensing process commonly referred to as the permit phase. This stage requires that teen drivers begin their driving experience under the supervision of an experienced driver. Crash rates for drivers in this licensing stage are known to be much lower than the crash rates of unsupervised teen drivers (Mayhew, 2003).

After completion of the permit phase, teen drivers typically graduate to a provisional stage of licensing. In the provisional stage of licensure, teen drivers are able to drive without the supervision of an adult. However, there are other restrictions that limit exposure to teen-specific crash causation factors. Teen drivers are generally prohibited from driving at night or limited in the number of allowed passengers they may transport. Night time driving and the presence of passengers are known to increase the crash risk for teen drivers (Williams, 2003). The rationale behind these restrictions is that teen drivers should first master basic driving skills before being exposed to the more complicated driving environments that are associated with these factors. Presumably, teen drivers who have graduated from a GDL program have accumulated the experience and skills that will allow them to perform better in the more complicated driving scenarios that accompany risk factors such as night time driving and driving with the distractions of passengers.

The majority of research that has addressed the successes of GDL has focused on the reductions in teen driver crashes and fatalities, relative to their pre-GDL peers. In general, GDL has been reported to be effective at reducing both of these rates for drivers in the GDL program (Shope et al., 2003; Simpson, 2003; Williams, 2006). The question remains, however, about what the factors are that have led to these reduced crash and fatality rates. As described in the previous chapter, the crash factors and the types of crashes that lead to teen crashes has not changed after GDL implementation. Instead, it has been suggested that the effectiveness in reducing crashes and fatalities may largely be due to reductions in exposure, rather than driving ability (Simpson, 2003; Fohr et al., 2005). Teens may be having fewer crashes simply because they are driving less. However, this has been a largely speculative hypothesis in the absence of reliable, age-specific travel exposure measures such as vehicle miles traveled. Frequently, teen driver populations and/or licensing counts have been used to express changes in exposure. However, these factors do not account for changes in travel exposure that are directly related to the regulations of GDL.

A primary goal of GDL regulation is to limit exposure to certain high-risk scenarios for teen drivers. Thus, to truly understand the effectiveness of GDL regulation, it is necessary to understand the extent that overall travel exposure has changed. Doherty (1997) sought to determine the travel exposure based effectiveness of GDL in Ontario, Canada. Doherty utilized age-specific travel logs to determine teen-driver crash rates. However, the data was only available for 1988, six years prior to GDL implementation. The authors acknowledged that this would be a confounding factor in their results, and generally overestimated the effectiveness of GDL because travel behaviors were likely to have changed as a result of regulation. Nonetheless, without age-specific data for both pre-GDL and post-GDL time periods, it was not possible to determine the extent of the over-estimation.

7.1.2 The National Household Travel Survey

The National Household Travel Survey (NHTS), formerly known as the National Personal Transportation Survey (NPTS), is a study conducted roughly every 6-8 years to identify changes in driving frequency within the United States. The last three iterations of the survey were conducted in 1995, 2001, and 2009. The collection methods have changed with various iterations of the dataset but they have all collected similar information and sought to quantify the travel frequencies and behaviors of drivers in the United States. The dataset is a collection of household travel surveys conducted over a year. All driving household members recorded each one-way trip within a 24-hour period. Trips that were taken in personal vehicles, public transportation, or other modes of travel such as walking or bicycling were all included. Each household, person, and trip was assigned a weight that represents their distribution of the annual travel behaviors of all American drivers. The 1995 dataset contains details of over 409,025 individual trips from 42,033 different households collected from May, 1995 to June, 1996. The 2009 dataset contains details of over 1,167,321 individual trips from 150,147 different households collected from March, 2008 to April, 2009. Details in the dataset include data such as trip distance and time, driver age, travel mode, trip time, and other demographic data. The data from survey year is publicly available from the NHTS website (FHWA, 2010).

The first GDL program was instituted in the United States in 1996 in Florida. Since this time, all states have adopted at least some part of GDL regulation. Therefore, it is now possible to assess the effects of GDL from a national perspective. Furthermore, the NHTS provides travel exposure for both pre-GDL (1995) and post-GDL (2009) teen driver populations in the United States. This provides a unique opportunity to quantify the travel exposure of teen drivers before and after GDL implementation in the United States.

Objective: Determine the effectiveness of GDL to reduce teen crashes per vehicle mile traveled in the United States.

7.2 Methods

The NHTS survey was used to determine the manner in which teen driver exposure has changed between a pre-GDL period (1995) and a post-GDL period (2009). The number of vehicle miles traveled, person miles traveled, and the number of travel minutes for teen drivers were determined from this dataset. Person miles traveled (PMT) were computed by multiplying the vehicle miles traveled for each trip by the number of the persons in the vehicle. The passenger restrictions placed on many GDL drivers is likely to have led to fewer passengers per vehicle, and therefore, fewer person miles traveled. Fatalities are more dependent on person involvement as opposed to vehicle involvement. As a result, fatality rates will be computed based on a PMT ratio, rather than a VMT ratio. Crash rates, however, were computed based on a VMT ratio. The travel time was computed to delineate between night- and day-time travel. The two night-time periods were defined as 9:00 p.m.-5:59 a.m. and midnight-5:59 a.m. All other travel time was considered day-time travel. Travel time, instead of vehicle miles traveled, was used for the night-time driving comparisons because it was not possible to determine what proportion of vehicle miles traveled were night- and day-time for the trips that overlapped these time periods. The appropriated trip-specific weights were applied to determine the national representation of teen driver exposure. Also, Taylor series linearization was used to estimate the variance of each exposure calculation while accounting for the stratification and clustering of the NHTS data. This allowed us to compute confidence intervals for the travel exposure estimates.

More traditional crash and fatality rates were computed as well. The number of crashes and fatalities per capita and per licensed driver were computed and compared between the pre-GDL and GDL periods. The population data was obtained from the United States Census Bureau (USCB, 2010). The licensing counts were obtained from the Federal Highway Administration's (FHWA) Annual Highway Statistics Report (FHWA, 2008). It should be noted that the FHWA licensing counts are known to have year-to-year consistency errors for some states (IIHS, 2006). Also, it is known that the reporting of the number of licensed teen drivers may be particularly error prone.

The National Automotive Sampling System General Estimates System (NASS/GES) is a large representative sampling of all crashes in the United States. The dataset is made up of roughly 60,000 police accident reports (PARs) annually from 1988-2008. All crash information from the PARs, including occupant information, vehicle information and crash information are electronically coded into a uniform dataset. The NASS/GES dataset was used to determine the changes in teen driver crashes nationally from a pre-GDL period to a GDL period. A three year range was used to define both the pre-GDL (1994-1996) and the GDL period (2006-2008). The 2008 crash year was the last year of data that was available at the time this study was conducted. However, a majority of the 2009 NHTS included surveys from 2008, thus there was still a significant overlap between the two datasets.

The Fatal Automotive Reporting System (FARS) is a database of all traffic related fatalities in the United States starting in 1975. The database is maintained by the National Highway Traffic Safety Administration (NHTSA) and includes all automotive related fatalities on public roadways where the person died of crash related injuries within 30 days of the crash. The FARS dataset was used to determine the changes in the number of fatalities that occurred in teen driven vehicles from a pre-GDL period to a GDL period. Similar to the NASS/GES analysis, three-year averages would were used to define the pre-GDL (1994-1996) and the GDL period (2006-2008). The latest available data from FARS was also in 2008.

All analyses were performed for individual teen ages. This will reflect the age-specific regulations that are associated with GDL programs nationally. Furthermore, all analyses were compared to the corresponding adult (35-55 year old) rates. This provides a normalizing population that is exposed to the same driving environment, and presumably would reflect any changes associated with exposure, crash rate, or fatality rate that are unrelated to GDL implementation. It was assumed that by comparing the rates of teen drivers to those of adults, the effects of these outside factors will be canceled out. The percent change for each age represents the change in the metric of interest, relative to the pre-GDL levels, as shown in Equation 12. The teen/adult % change is calculated in a similar manner but is with respect to the change in the metric of interest, normalized to the adult ratio, relative to the pre-GDL levels.

$$\% \ Change = \frac{\Delta Metric}{Pre - GDL \ (Metric)} \qquad \textbf{Equation 12}$$

$$Teen/Adult \ \% \ Change = \frac{\Delta \left(\frac{Metric_{Teen}}{Metric_{Adult}}\right)}{\left(\frac{Metric_{Teen}}{Metric_{Adult}}\right)_{Pre-GDL}} \qquad \textbf{Equation 13}$$

Due to the nature of the datasets used, confidence intervals were not computed. When combining two or more independent survey datasets, it is not possible to compute the covariance between to random variables (e.g. number of crashes and VMT). Therefore, it was not possible to estimate the variance of a ratio of these two variables. As a result, the results presented in this study are not presented with statistical significance or with confidence intervals. Previous studies that have presented the ratios of variables sampled from the NHTS (a.k.a. NPTS) and NASS/GES survey datasets did so without confidence limits as well (Williams et al., 1995; Williams et al., 2002; Kweon et al., 2003).

7.3 Results

The pre-GDL and GDL era estimates for VMT and PMT are presented in Table 26. The estimates and counts for the number of licensed drivers, population, crashes, and fatalities are presented in Table 27. These values from these two tables were the basis for this effectiveness study. The percent change and percent change of the teen/adult ratio for VMT, PMT, licensed driver counts, population, crashes and fatalities are presented in Table 28. VMT for 16 and 17 year old drivers decreased from the pre-GDL period to the GDL period by 39% and 23%, respectively. Similarly, the PMT for 16 and 17 year old drivers was 41% and 30% less in the GDL era, respectively, and the number of licensed drivers was 15% and 3% less. However, VMT was 13% greater, PMT was 12% greater, and the number of licensed drivers was 16% greater for 18-20 year old drivers in the GDL era when compared to the pre-GDL period. Furthermore, the VMT, PMT, and licensed driver counts for adults were 17%, 31%, and 18% greater in the GDL era, respectively. The population increased by 18-26% across all ages from the pre-GDL period to the GDL time period.

Crashes were less frequent in the GDL period compared to the pre-GDL period for all age groups. The largest reductions were seen for 16 and 17 year old drivers. The number of crashes involving 16 year old drivers was 42% less and 17 year old driver crashes were 19% less in the GDL era when compared to the pre-GDL period. The number of fatalities was also less for all teen drivers, but not for adults. The number of fatalities in crashes involving 16 year old drivers was 44% less and fatalities in 17 year old crashes was 19% less in GDL era compared to the pre-GDL period. The number of fatalities in crashes involving 18-20 year old was 3-4% less in the GDL era. In contrast, the number of fatalities in adult driver crashes was 16% greater in the GDL era.

Three crash rates were evaluated: crashes per age-specific VMT, crashes per licensed driver, and crashes per population. Fatalities were normalized by age-specific PMT, the number of licensed drivers, and population. Each of these metrics is presented in Table 29 for the pre-GDL and GDL periods. Furthermore, each of these rates was compared to the same rate for adult drivers in the pre-GDL and GDL periods. The rate of crashes per capita was shown to be much less in the GDL era as compared to the pre-GDL period for teen drivers. In particular, 16 year old drivers had a crash rate of 92.62 crashes / 1,000 16 year olds in the pre-GDL period but a rate of only 45.89 crashes / 1,000 16 year olds in the GDL era. Similarly, 17 year old drivers had experienced a rate of 102.45 crashes / 1,000 17 year olds in the pre-GDL period but a rate of only 69.09 crashes / 1,000 17 year olds was seen in the GDL era. However, the adult drivers also had a lower in their per capita crash rate in the GDL period (38.95 crashes / 1,000 people) when compared to the pre-GDL period (49.75 crashes / 1,000 people). However, because the travel exposure, i.e. VMT, for teen drivers decreased more than teen population between the pre-GDL and GDL time periods, the crash rates based on this exposure metric showed a different result. The number crashes per VMT of 16 year old drivers was largely unchanged from the pre-GDL period (3.42 / 100k VMT) to the GDL period (3.29 / 100k VMT). The travel exposure normalized crash rate for 17 year old increased slightly from the pre-GDL period (1.96 / 100k VMT) to the GDL period (2.08 / 100k VMT). In contrast, this same crash rate decreased for 18-20 year old drivers and adult drivers from the pre-GDL period to the GDL period.

The travel exposure-based crash rates of teen drivers were compared to the same rates for adults in the pre-GDL and GDL periods, as shown in Table 30. In the pre-GDL period it was found that the number of crashes / VMT were 8.64 time greater for 16 year old drivers than for adults and 10.39 times greater in the GDL era. Similarly, the number of crashes / VMT for 17 year old drivers was 4.97 times greater than for adults in the pre-GDL period and 6.57 times greater after

GDL implementation. In comparison, the factor by which the number of crashes / VMT for 18-20 year olds was greater than that of adults was largely the same before and after GDL implementation.

Similar to the population normalized crash rates, the rate of fatalities per capita, as shown in Table 29, decreased for all driver ages. Again, however, when the number of fatalities was normalized by the travel exposure of each age, the results were found to be age-dependent. The rate of fatalities per 100 million PMT was 6.24 in the pre-GDL period for 16 year old drivers and 5.91 in the GDL period. However, this same rate was 3.37 for 17 year old drivers in the pre-GDL period but increased slightly to 3.91 in the GDL era. In contrast, the fatality rate per 100 million PMT for 18-20 year old drivers and adults was lower in the GDL period when compared to the pre-GDL period. These travel exposure-based fatality rates of teen drivers were compared to the same rates for adults in the pre-GDL and GDL periods, as shown in Table 30. The number of fatalities / PMT was 11.21 times greater for 16 year old drivers than for adults in the pre-GDL era and 11.97 times greater in the GDL era. However, the number of fatalities / PMT for 17 year old drivers was 6.05 times greater than for adults in the pre-GDL period and 7.92 times greater after GDL implementation. In contrast, the factor by which the number of fatalities / PMT for 18-20 year olds was greater than that of adults was largely the same before and after GDL implementation.

Finally, night driving time was computed by age for both the 9:00 p.m. - 5:59 a.m. and midnight-5:59 a.m. time periods. The number of crashes was normalized by night-time vehicle travel time and fatality counts were normalized by night-time person travel time. These metrics are presented in Table 31. The number of crashes / 10 Million travel minutes for the 9:00 p.m.-5:59 a.m. travel period was lower after GDL implementation for all ages except 20-year old drivers. Also, the teen-to-adult ratio of crashes per vehicle travel minutes, as shown in Table 32, was less for all ages except 20 year olds in the GDL period when compared to the pre-GDL period. Alternatively, the number of crashes per travel minute for the midnight-5:59 a.m. travel period was only lower for 18-19 year olds and adult drivers in the post-GDL period. Furthermore, the number of crashes / 10 million travel minutes between midnight-5:59 a.m. for 16 year olds was 400.5 in the pre-GDL period and 939.8 in the GDL period. Similarly, the number of crashes / 10 million travel minutes for 17 year olds was 410.0 in the pre-GDL period and 613.7 after GDL implementation. As a result, the number of crashes / vehicle travel time between midnight and 5 a.m. for 16 year olds was 14.91 times greater than the same adult rate in the pre-GDL but 36.51 times greater after GDL implementation. Similarly, the number of crashes / vehicle travel time between midnight- 5:59 a.m. for 17 year olds was 15.27 times greater than the adult rate in the pre-GDL but 23.84 times greater after GDL implementation.

The number of fatalities per minute of person travel between 9:00 p.m. - 5:59 a.m. was lower for all ages except for adult drivers in the GDL period when compared to the pre-GDL period. However, number of fatalities per minute of person travel from midnight-5:59 a.m. was much greater for 16- and 17 year old drivers in the GDL period when compared to the pre-GDL period.

For 16 year olds, there were 2.58 fatalities / 10 million person travel minutes before GDL. In contrast, there were 10.16 fatalities / 10 million person travel minutes after GDL implementation. For 17 year old drivers, there were 2.71 fatalities / 10 million person miles traveled before GDL. After GDL, there were 7.35 fatalities / 10 million person miles traveled for 17 year old drivers. For 18-20 year old drivers, this fatality ratio was largely unchanged between the two GDL periods. When the number of fatalities / person travel time for teen drivers was compared to the same rate for adults, as shown in Table 32, it was found that the 16 and 17 year old drivers had large increases in their relative fatality rates but 18-20 year old drivers showed a slight decrease in their relative fatality rates. For 16 year olds it was found that the number of fatalities / person travel time from midnight-5:59 a.m. was 14.03 times greater than that of adults in the pre-GDL period but 48.45 times greater after GDL implementation. Similarly, the number of fatalities / person travel time from midnight-5:59 a.m. for 17 year old drivers was 14.75 times greater than that of adults in the pre-GDL period but 35.08 times greater after GDL implementation.

Table 26. Pre-GDL and post-GDL distributions of vehicle miles traveled (VMT), person miles traveled (PMT), vehicle night-time travel minutes, and person night-time travel minutes by age. Estimates are given with 95% confidence intervals.

Age	VMT (billions)	PMT (billions)	Vehicle Night Travel Minutes (billions) 9 p.m.- 5:59 am	Vehicle Night Travel Minutes (billions) 12a.m.- 5:59 am	Person Night Travel Minutes (billions) 9 p.m.- 5:59 am	Person Night Travel Minutes (billions) 12a.m.- 5:59 am
			Pre-GDL			
16	**9.9** (8.9-10.8)	**15.9** (14.3-17.6)	**2.0** (1.5-2.5)	**0.3** (0.1-0.5)	**3.3** (2.5-4.1)	**0.5** (0.2-0.9)
17	**18.9** (15.5-22.3)	**31.7** (23.1-40.3)	**3.5** (2.6-4.5)	**0.4** (0.1-0.6)	**6.3** (3.7-9.0)	**0.8** (0.1-1.6)
18	**28.9** (26.3-31.3)	**42.6** (38.2-47.0)	**6.8** (5.7-7.8)	**1.6** (1.1-2.2)	**11.2** (9.0-13.4)	**2.9** (1.5-4.3)
19	**27.9** (24.2-31.6)	**43.0** (35.7-50.4)	**6.6** (5.0-8.2)	**2.1** (1.3-3.0)	**10.8** (8.1-13.5)	**3.8** (2.1-5.5)
20	**26.0** (23.2-28.8)	**35.2** (31.2-39.2)	**5.9** (4.4-7.2)	**1.8** (1.2-2.3)	**7.2** (5.5-9.0)	**2.2** (1.4-3.1)
16-17	**28.8** (25.4-32.1)	**47.6** (39.0-56.2)	**5.5** (4.6-6.4)	**0.7** (0.4-0.9)	**9.6** (7.1-12.2)	**1.4** (0.4-2.4)
16-18	**57.7** (53.8-61.6)	**90.2** (80.7-99.7)	**12.3** (11.1-13.5)	**2.3** (1.9-2.7)	**20.9** (17.7-24.0)	**4.2** (2.8-5.7)
18-20	**82.8** (78.2-87.5)	**120.8** (112.0-129.6)	**19.3** (17.3-21.2)	**5.6** (4.7-6.4)	**29.3** (26.0-32.6)	**8.9** (6.9-11.0)
16-20	**111.6** (105.9-117.3)	**168.4** (156.1-180.7)	**24.8** (22.6-26.9)	**6.3** (5.3-7.1)	**38.9** (34.7-43.1)	**10.3** (8.1-12.5)
35-55	**953.4** (932.7-974.1)	**1524.1**(1472.2-1576.0)	**130.0** (122.1-137.9)	**59.0** (53.6-64.4)	**211.9** (182.7-241.1)	**86.0** (66.4-105.7)
			Post-GDL			
16	**6.0** (4.8-7.2)	**9.4** (8.2-10.7)	**1.2** (0.8-1.6)	**0.1** (0.0-0.1)	**2.1** (1.3-2.9)	**0.1** (0.0-0.2)
17	**14.5** (12.2-16.9)	**22.0** (19.4-24.7)	**3.4** (2.2-4.6)	**0.2** (0.1-0.3)	**5.9** (2.0-9.7)	**0.2** (0.1-0.3)
18	**32.4** (26.2-38.6)	**49.2** (40.3-58.1)	**9.0** (6.2-11.7)	**1.7** (1.0-2.4)	**14.7** (9.1-20.3)	**2.5** (1.5-3.6)
19	**32.8** (25.9-39.7)	**47.6** (40.1-55.1)	**8.6** (6.1-11.2)	**2.6** (1.5-3.7)	**12.9** (8.9-16.8)	**3.8** (2.1-5.6)
20	**28.3** (22.9-33.7)	**38.3** (33.2-43.5)	**5.4** (4.2-6.5)	**1.7** (0.1-2.6)	**7.6** (5.9-9.3)	**2.5** (1.4-3.5)
16-17	**20.5** (17.9-23.0)	**31.5** (28.6-34.3)	**4.6** (3.4-5.9)	**0.3** (0.1-0.4)	**8.0** (4.1-11.9)	**0.3** (0.2-0.5)
16-18	**52.9** (46.2-59.6)	**80.7** (71.4-89.9)	**13.6** (10.7-16.6)	**2.0** (1.3-2.6)	**22.7** (16.0-29.4)	**2.9** (1.8-4.0)
18-20	**93.5** (83.2-103.8)	**135.1** (122.7-147.5)	**23.0** (19.2-26.7)	**6.0** (4.5-7.6)	**35.2** (28.4-42.0)	**8.8** (6.5-11.1)
16-20	**114.0** (103.0-125.0)	**166.5** (153.7-179.4)	**27.6** (23.6-31.6)	**6.3** (4.7-7.8)	**43.2** (35.3-51.1)	**9.2** (6.8-11.5)
35-55	**1112.5** (111.5-1180.2)	**1995.6** (1861.8-2129.4)	**139.7** (130.9-148.6)	**64.0** (57.4-70.6)	**242.9** (218.5-267.2)	**90.9** (77.3-104.5)

Table 27. Pre-GDL and GDL distributions of the number of licensed drivers, population, crashes and fatalities by age.

Age	Pre-GDL Licensed Drivers	Pre-GDL Population	Pre-GDL Crashes	Pre-GDL Fatalities	GDL Licensed Drivers	GDL Population	GDL Crashes	GDL Fatalities
16	1,563,571	3,635,924	336,756	995	1,328,511	4,286,688	196,736	558
17	2,250,594	3,627,534	371,651	1,066	2,172,041	4,365,358	301,601	863
18	2,563,026	3,523,680	379,803	1,239	2,894,449	4,456,650	340,719	1,191
19	2,688,274	3,585,222	352,503	1,198	3,224,766	4,311,245	323,318	1,160
20	2,880,051	3,602,987	323,783	1,141	3,341,645	4,262,791	303,355	1,105
16-17	3,814,165	7,263,458	708,407	2,061	3,500,552	8,652,046	498,337	1,421
16-18	6,377,191	10,787,138	1,088,210	3,300	6,395,001	13,108,696	839,056	2,612
18-20	8,131,351	10,711,889	1,056,088	3,578	9,460,860	13,030,686	967,392	3,456
16-20	11,945,516	17,975,347	1,764,495	5,639	12,961,412	21,682,732	1,465,729	4,877
35-55	71,977,954	75,792,427	3,770,806	8,484	84,610,940	90,394,963	3,520,945	9,861

Table 28. Percent change and percent change of the teen/adult ratio in vehicle miles traveled (VMT), number of licensed drivers, population, crashes and fatalities by age.

Age	VMT % Change	VMT Teen/Adult % Change	PMT % Change	PMT Teen/Adult % Change	Licensed Drivers % Change	Licensed Drivers Teen/Adult % Change	Population % Change	Population Teen/Adult % Change	Crashes % Change	Crashes Teen/Adult % Change	Fatalities % Change	Fatalities Teen/Adult % Change
16	-39%	-48%	-41%	-55%	-15%	-28%	18%	-1%	-42%	-37%	-44%	-52%
17	-23%	-34%	-30%	-47%	-3%	-18%	20%	1%	-19%	-13%	-19%	-30%
18	12%	-4%	16%	-12%	13%	-4%	26%	6%	-10%	-4%	-4%	-17%
19	17%	1%	11%	-16%	20%	2%	20%	1%	-8%	-2%	-3%	-17%
20	9%	-7%	9%	-17%	16%	-1%	18%	-1%	-6%	0%	-3%	-17%
16-17	-29%	-39%	-34%	-50%	-8%	-22%	19%	0%	-30%	-25%	-31%	-41%
16-18	-8%	-21%	-11%	-32%	0%	-15%	22%	2%	-23%	-17%	-21%	-32%
18-20	13%	-3%	12%	-15%	16%	-1%	22%	2%	-8%	-2%	-3%	-17%
16-20	2%	-12%	-92%	-94%	9%	-8%	21%	1%	-17%	-11%	-14%	-26%
35-55	17%	0%	31%	0%	18%	0%	19%	0%	-7%	0%	16%	0%

Table 29. Crash and fatality rates before and after GDL implementation for teen and adult drivers.

	Crashes / 100,000 VMT		Crashes / 100 Licensed Drivers		Crashes / 1,000 Population		Fatalities / 100 Million PMT		Fatalities/10,000 Licensed Drivers		Fatalities/ 10,000 Population	
Age	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL
16	3.42	3.29	21.54	14.81	92.62	45.89	6.24	5.91	6.36	4.20	4.00	1.87
17	1.96	2.08	16.51	13.89	102.45	69.09	3.37	3.91	4.74	3.97	4.68	2.97
18	1.31	1.05	14.82	11.77	107.79	76.45	2.91	2.42	4.83	4.12	5.60	4.03
19	1.26	0.99	13.11	10.03	98.32	74.99	2.78	2.44	4.46	3.60	5.40	4.17
20	1.25	1.07	11.24	9.08	89.87	71.16	3.24	2.88	3.96	3.31	5.12	4.15
16-17	2.46	2.43	18.57	14.24	97.53	57.60	4.33	4.51	5.40	4.06	4.34	2.42
16-18	1.89	1.59	17.06	13.12	100.88	64.01	3.66	3.24	5.17	4.08	4.75	2.97
18-20	1.27	1.03	12.99	10.23	98.59	74.24	2.96	2.56	4.40	3.65	5.37	4.12
16-20	1.58	1.29	14.77	11.31	98.16	67.60	3.35	2.93	4.72	3.76	4.96	3.44
35-55	0.40	0.32	5.24	4.16	49.75	38.95	0.56	0.49	1.18	1.17	2.27	1.99

Table 30. Teen / Adult crash rate ratios before and after GDL implementation.

	Crashes / VMT		Crashes / Licensed Drivers		Crashes / Population		Fatalities / PMT		Fatalities / Licensed Drivers		Fatalities/ Population	
Age	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL
16	8.64	10.39	4.11	3.56	1.86	1.18	11.21	11.97	5.40	3.60	1.76	0.94
17	4.97	6.57	3.15	3.34	2.06	1.77	6.05	7.92	4.02	3.41	2.06	1.49
18	3.32	3.32	2.83	2.83	2.17	1.96	5.23	4.90	4.10	3.53	2.47	2.03
19	3.19	3.12	2.50	2.41	1.98	1.93	5.00	4.93	3.78	3.09	2.38	2.10
20	3.15	3.39	2.15	2.18	1.81	1.83	5.83	5.84	3.36	2.84	2.26	2.09
16-17	6.22	7.68	3.55	3.42	1.96	1.48	7.78	9.13	4.58	3.48	1.91	1.22
16-18	4.77	5.01	3.26	3.15	2.03	1.64	6.57	6.55	4.39	3.51	2.09	1.49
18-20	3.22	3.27	2.48	2.46	1.98	1.91	5.32	5.18	3.73	3.13	2.37	2.07
16-20	4.00	4.06	2.82	2.72	1.97	1.74	6.02	5.93	4.00	3.23	2.18	1.73
35-55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 31. Night Crash and fatality rates based on travel time for teen and adult drivers.

Age	Crashes / 10 Million Vehicle Travel Minutes				Fatalities / 10 Million Person Travel Minutes			
	9pm-5:59am		12am-5:59am		9pm-5:59am		12am-5:59am	
	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL
16	251.2	199.5	400.5	939.8	1.015	0.918	2.58	10.16
17	157.1	125.3	410.0	613.7	0.685	0.583	2.71	7.35
18	98.9	65.1	156.6	143.2	0.498	0.373	1.17	1.28
19	97.3	69.4	135.0	104.3	0.546	0.433	1.01	0.93
20	95.7	105.6	149.0	159.9	0.766	0.730	1.64	1.51
16-17	190.8	144.9	405.7	694.0	1.397	1.158	5.40	10.50
16-18	140.0	92.3	229.2	213.7	1.080	0.798	3.03	3.01
18-20	97.4	76.2	145.9	131.2	0.881	0.724	1.93	1.74
16-20	118.1	87.7	173.5	153.7	0.995	0.797	2.30	2.09
35-55	30.9	26.9	26.9	25.7	0.134	0.138	0.18	0.21

Table 32. Night drive time Teen / adult crash and fatality rate ratios before and after GDL implementation.

Age	Crashes / 10 Million Vehicle Travel Minutes				Fatalities / 10 Million Person Travel Minutes			
	9pm-5:59am		12am-5:59am		9pm-5:59am		12am-5:59am	
	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL	Pre-GDL	GDL
16	8.12	7.42	14.91	36.51	7.58	6.67	14.03	48.45
17	5.08	4.66	15.27	23.84	5.12	4.24	14.75	35.08
18	3.20	2.42	5.83	5.56	3.72	2.71	6.35	6.12
19	3.15	2.58	5.03	4.05	4.08	3.15	5.47	4.42
20	3.09	3.93	5.55	6.21	5.72	5.30	8.90	7.20
16-17	6.17	5.39	15.11	26.96	10.43	8.41	29.32	50.08
16-18	4.53	3.43	8.53	8.30	8.06	5.80	16.48	14.35
18-20	3.15	2.83	5.43	5.10	6.58	5.26	10.51	8.31
16-20	3.82	3.26	6.46	5.97	7.43	5.79	12.51	9.97
35-55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

7.4 Discussion

This is the first study to identify the effectiveness of GDL from both a national and travel exposure-based perspective. Previous studies have shown that that teen driver crashes and fatalities have decreased since the implementation of GDL. However, it is not known if this is because GDL has produced better teen drivers or if teen drivers are simply limited in their exposure. This following section will explore this question from a travel-exposure perspective.

7.4.1 Changes in Crash and Fatality Counts for Teen Drivers

The annual count of crashes and fatalities for both 16-17 year old drivers and 18-20 year old drivers was much less after GDL implementation when compared to the pre-GDL period. However, the percentage decrease for 18-20 drivers was less than that of 16-17 year old drivers. A primary objective of GDL was to reduce the number of crashes and fatalities for teen drivers. The results of our study support the conclusion that GDL implementation is associated with reductions in these events. Our study confirms the findings of others who have reported similar reductions in the annual crashes and fatalities for GDL drivers in different jurisdictions across the United States and abroad (Bouchard, 2000; Agent, 2001; Foss et al., 2001; Sagberg, 2001; Ulmer, 2001; Lam, 2003; Fohr et al., 2005; Hyde et al., 2005; Kirley et al., 2008). Frequently, however, it has been reported that reductions in the number of fatalities and crashes occurred for 16 year old drivers and not necessarily for older teen drivers (Agent, 2001; Ulmer, 2001). Typically, 16 year old drivers are still subject to the regulations of GDL while older teens have graduated from the program. Nonetheless, our study has been shown that GDL is associated with significant public health and societal benefits in the form of reductions in the number of teen driver crashes and fatalities.

These results are not surprising when considering the nature of GDL regulations. In general, most GDL programs include restrictions that are targeted at limiting teen driver exposure to the most risky driving scenarios. In general, restrictions include a ban on night driving and on the number of allowed passengers. Both of these factors are known to increase teen driving crash risk (Williams et al., 1997; Chen et al., 2000). These restrictions are meant to allow the teen drivers to acquire basic driving skills before they are required to address more complicated driving situations. Deery (1999) showed that teen drivers are quite capable of acquiring basic driving skills, but their ability to acquire the higher order skills necessary to navigate riskier driving environments are limited. As a result, the restrictions associated with GDL are intended to allow teens more time to develop the higher order skills needed to address more complicated driving scenarios.

7.4.2 Changes in per Capita and per Licensed Driver Crash and Fatality Rates

Population counts, which are commonly used as a surrogate for teen driver exposure, are likely to have increased with the widespread implementation of GDL. As the number of teens increased, presumably so would number of crashes and fatalities for teen drivers. Common practices are to normalize the number of crashes or fatalities by age-specific population or the number of licensed drivers. Our study has shown that the population of 16-20 year olds in the United States increased by 21% from 1995 to 2009. However, it was found that the estimated number of licensed 16 year old drivers decreased by 15% and the number of licensed 17 year old drivers decreased by 3%. At the same time, the number of licensed 18-20 year old drivers increased by 16%. The reasons for the decrease in 16-17 year old licensed drivers may be related to teen drivers avoiding age-specific regulations of GDL. Nonetheless, the changes in population and licensing rates highlight the need to use normalizing metric when computing the effectiveness of GDL regulation.

Normalizing the number of crashes and fatalities by population and licensing counts has been a common practice in reports on GDL effectiveness in the United States (Ulmer, 1999; Ulmer, 2000; Agent, 2001; Foss et al., 2001; Shope et al., 2001; Ulmer, 2001; Rice et al., 2004; Shope et al., 2004; Fohr et al., 2005; Hyde et al., 2005; Zwicker, 2006; Males, 2007; Kirley et al., 2008; Neyens et al., 2008; Williams et al., 2010). In general, it has been shown that the rate of crashes and fatalities per capita or licensed driver has decreased, particularly for 16 and 17 year old drivers when comparing GDL drivers to pre-GDL drivers. The results of our study support these findings. We found that the number of crashes and fatalities for all ages of teen drivers, when normalized by population, was much lower after GDL implementation when compared to the pre-GDL period. Furthermore, the per capita crash and fatality rates for 16 year old drivers after GDL implementation were less than half of the pre-GDL rate. It was also shown that the crash and fatality rates, when normalized by the number of licensed drivers for all teen drivers, decreased after GDL implementation. However, the reductions in the licensed driver rates were less than the reductions in the per capita rates. Interestingly, the per licensed driver and per capita fatality and crash rates for adult drivers were also lower in the GDL era when compared to the pre-GDL era. This suggests that there were factors, unrelated to GDL implementation, that were paying a role in the crash and fatality rate reductions seen for all ages.

To account for the changes in the overall driving environment that have led to a reduction in the crash and fatality rates for all drivers, the crash and fatality rates for teen drivers were compared to those of adult drivers. Changes in the teen/adult crash relative rates, when normalized by population and licensing counts, were found to be age dependent. 16-17 year old drivers saw the largest reductions in these relative rates from the pre-GDL era to the GDL era. 18-20 year old drivers had relatively similar relative crash rates in the pre-GDL and GDL periods. However, the relative rate for the number of fatalities per capita and per licensed driver comparing teen and adult drivers decreased from the pre-GDL period to the GDL period. This result suggests that the restrictions of GDL have been associated with reductions in the relative teen driver crash and fatality rates for those who are subject to the regulations of GDL or for those who have just graduated from GDL. However, the benefits of GDL do not appear to extend to a reduced crash rate for 18-20 year old drivers. There does appear to be a reduction in more severe crashes, as evident in the lower fatality rates for drivers in this age group.

7.4.3 Changes in Travel Exposure

A primary goal of this study was to identify the role of travel exposure in the effectiveness of GDL. Other research has questioned the source of GDL effectiveness (Simpson, 2003). Specifically, it was unknown if GDL was truly affecting driver behavior, reducing the threats associated with the most difficult driving scenarios (e.g. night-time driving or driving with passengers), reducing exposure to all driving situations, or a combination of these factors. Our study has shown that VMT was much lower after GDL implementation when compared to the pre-GDL period for 16-17 year old drivers. Furthermore, our study found that the change in the annual rate of PMT was lower in the GDL period when compared to the change in VMT for all 16-20 year old drivers. This suggests that there has been a reduction in the number of passengers for all young drivers, even for those who are not under the regulations of GDL. It is known that passenger distractions are a teen-specific crash causation factor (Chen et al., 2000; Williams, 2003). This, in itself, has likely contributed to the lower crash and fatality rates seen in the post-GDL period for teen drivers. Also, the night-time driving VMT, particularly for midnight - 5:59 a.m. was much less for 16-17 year old drivers in the GDL period. Furthermore, increases in the time spent night driving for 18-20 year olds was not proportional to the increases in overall driving (VMT) for this age group (13% increase in VMT vs. 7% increase in night driving time). Night-time driving is known to be particularly dangerous for young drivers and it is likely that the lower exposure for young drivers in the GDL period has been integral in the overall reduction in fatalities.

7.4.4 Changes in Travel Exposure-Based Crash and Fatality Rates

The vehicle miles traveled and person miles traveled were used to determine the level of exposure for drivers. Population counts and number of licensed drivers are less than ideal measures of exposure. For instance, not all teens are licensed drivers. Also, licensing and population counts do not account for changes in travel exposure that may result from the restrictions placed on GDL drivers. Our study has suggested that the rate of crashes and fatalities / VMT has declined slightly for 16 year olds and increased slightly for 17 year olds. The rate of crashes and fatalities / VMT for 18-20 year olds decreased as well. Interestingly, the number of crashes / VMT for adult drivers also decreased by 20% (0.40 crashes / 100k VMT vs. 0.32 crashes / 100k VMT) from the pre-GDL period to the GDL period. The reason that the adult crash rate decreased so substantially is unknown. It is possible that higher traffic volumes resulting from increases in the number of licensed drivers and the increases in VMT have decreased the crash risk.

The fact that the crash and fatality rates declined for adult drivers along with teen drivers suggests that factors outside of GDL have contributed to an overall reduction in crash risk for all drivers. To control for these effects, we compared the travel exposure-based crash and fatality rates of teen driver to those of adults. Prior to GDL implementation, 16 year old drivers were found to have a crash / VMT rate that was 8.64 times greater than that of adults. This result supports the findings of previous research that has suggested similar elevated crash risks for teen drivers (Williams et al., 1995). However, it was found that the number of crashes / VMT for 16 year old drivers after GDL implementation was 10.39 times greater than that of adults after GDL implementation. Similarly, the number of crashes / VMT for 17 year old drivers was 4.97 times greater than that of adults prior to GDL implementation but 6.57 times greater after GDL implementation. Similar comparisons of 18-20 year old driver crash rates to those of adults showed little change from the pre-GDL period to the GDL period.

The number of fatalities per passenger mile traveled was worse for teen drivers after GDL implementation. The number of fatalities / PMT for 16 year old drivers was 11.21 times greater than the same ratio for adults before GDL and increased slightly to a 11.97 times greater rate after GDL. For 17 year old drivers, the number of fatalities / PMT was 6.05 times greater than the same rate for adult driver before GDL but increased to a 7.92 times greater after GDL. The change in this fatality ratio was over four and a half times larger for 17-year old divers than for 16-year old drivers. However, 16-year old drivers had a larger relative fatality rate in the GDL period. The number of fatalities / PMT for 18-20 year old drivers was roughly five times greater than the same rate for adults in both the pre-GDL and GDL periods. Overall, these results suggest that 16 and 17 year old drivers have a higher crash risk and a higher fatality risk relative to adult drivers after GDL implementation. However, the elevated relative crash and fatality risks for 18-20 year old drivers has generally remained the same.

Previous research has suggested that novice driver crash rates are highest when they first begin unsupervised driving (Mayhew et al., 2003). In most GDL programs, the minimum age for this stage is 16-years old. Restrictions are placed on drivers of this age to lower their exposure to crash-causing scenarios. It is possible that the restrictions have hampered the ability of the newly licensed drivers to adjust to challenging situations when they are presented, resulting in a higher relative crash rate. In most GDL programs, 17-years old is the minimum age at which unsupervised and unrestricted driving can begin. Drivers of this age had an even higher relative crash and fatality risk rate than that of 16 year olds. Therefore, it is possible that the lifting of restrictions, i.e. 17 years old, has contributed to an even larger relative increase in the ratio of crashes/VMT than was seen for 16-year old drivers. This may be because teens have not acquired the specific skills associated with navigating safely in the complicated driving scenarios that had previously been restricted, e.g night-time driving and driving with passengers.

Brown et al (1988) reported that teens are often not aware of their own driving abilities. A recent study examined the driving abilities of Finnish and Dutch novice drivers and found that 30-40% of novice drivers over estimated their own driving abilities (Mynttinen et al., 2009). It is possible that they are unable to properly assess their abilities in the new driving environments following the removal of GDL restrictions. Furthermore, the large change in the 17-year old fatality rate, relative to adult drivers, suggests that these drivers are particularly susceptible to a fatal crash in these new environments. However, it appears that teens do begin to acquire the skills with more licensing experience, i.e. 18-20 year old drivers. Fortunately, a lower fatality rate, relative to adult drivers, was seen for 18-year old drivers in the GDL period when compared to the pre-GDL period. The fatality ratio was roughly the same in both the pre-GDL and GDL periods for 19-20 year old drivers. This suggests that any dis-benefits resulting from limiting exposure are not extended beyond the first few years of licensure.

7.4.5 Night Driving Crash and Fatality Rates

Night-time driving is a particularly dangerous time for new drivers. The restrictions on night-time driving for teen drivers are designed to limit the exposure of newly licensed drivers to the night-specific crash causing factors until the basic driving skills can be developed in the day time. The results from our study have shown that night-time driving exposure was much lower in the GDL period for 16-17 year old drivers when compared to their pre-GDL peers. The crash and fatality rates for 16-17 year old drivers were lower during the hours of 9p.m.-5:59a.m after GDL implementation. However, these same rates for the hours of midnight-5:59a.m. were much higher after GDL implementation. In fact, the rate of crashes / vehicle travel time was over twice as high for 16-year old drivers after GDL implementation and the rate of fatalities / person travel time was three and a half times higher after GDL for driving that occurred between midnight-5:59a.m. For 17 year olds, the number of crashes / vehicle travel time was 15.27 times that of adults before GDL implementation. After GDL it was 23.84 times greater. The 17 year old fatality / person travel time relative rates after GDL were over twice as high when compared to the pre-GDL period.

For 16-year olds, these results suggest that while they are generally limited in their night driving, when they did drive at night in the GDL period, they were unprepared for the challenges of that environment. Furthermore, 17-year old drivers, the age at which night-time and passenger restrictions can be lifted in most GDL programs, also appear to be unprepared for the challenges of night-time driving. Fortunately, it appears that 18-20 year old drivers acquire the skills necessary for addressing the challenges of night-time driving. In fact, the crash and fatality rates for these ages, relative to adults, were generally less in the GDL era when compared to the pre-GDL period. This suggests that any benefit from limiting exposure to night-time driving may be delayed until the driver has more experience in that environment.

7.4.6 Implications of Results

Overall, it appears that GDL has reduced the number of teen driver crashes and fatalities in vehicles driven by teens. From this perspective, GDL has succeeded in reducing the burden of societal and health costs associated with teen drivers in the United States. Motor vehicles continue to be the leading cause of death for all persons aged 13-19 years old, despite an overall decline in teen fatalities over the last two decades (IIHS, 2009). Therefore, any reduction in the number of teen driver related fatalities is a positive result.

Our study does not show, however, that VMT normalized crash rates have improved when compared to adults. We speculate that restrictions associated with GDL may actually hinder the ability of teen driver to address crash causing scenarios. It is possible that GDL actually contributes further to an over-estimation of ability for teen drivers during restricted driving periods. Basic driving skills, acquired during restricted driving may cultivate a false confidence that contributes to higher crash risk after the restrictions are lifted. Teen drivers may not recognize that when they are permitted to drive in more challenging environments that their current driving abilities may not be adequate. Ferguson (2003) has reported that secondary driving courses and/or exit testing may help correct some of these issues; although neither of these methods have been proven to be effective outside of simulated environments. Nonetheless, it is possible that these interventions may at least instill a cautious awareness for teens regarding their own abilities.

We conclude that GDL is associated with a reduction in travel exposure. However, it is unclear if GDL has been effective at truly changing driving behaviors. As noted by Ferguson, it is possible that the restrictions of GDL may not be able to address all areas of teen driver crash risk directly. The real issue of changing teen driver behavior is complicated and not homogenous across all teen drivers. As such, there is plenty of room for improvement in the processes for licensing teen drivers.

7.4.7 Limitations

This study has several limitations which affect the interpretation of results. One of the limitations is the assumption that the exposure measures derived from one year data before GDL implementation and one year after GDL implementation are representative of the exposure for drivers in the pre-GDL and GDL time periods used in the crash and fatality determination methods. In particular, it is known that the majority of crashes and fatalities included in the GDL period of this analysis occurred before the fall of 2008. However, the exposure measure collection period overlapped the fall of 2008 and extended into early 2009. This is the time when the United States fell into a large economic downturn. As a result, it may be reasonable to assume that driving, especially teen driving, became more of a discretionary task. As such, the estimates of exposure may be lower than what actually occurred in the time period in which the crash and fatality data were collected. This would result in larger crash and fatality risks from the travel-exposure basis. In other words, it may be assumed that these results represent a “worst case scenario” for teen driver crash and fatality rates.

Also, the crash and exposure metrics were derived from weighted samples sets, which have their own inherent sampling errors. Unfortunately, when combining these datasets, it was not possible to compute confidence intervals due to the fact that the variances of the resulting ratios could not be estimated without a measure of covariance between the random variables. Therefore, all results are meant to represent general trends in teen driving over time, but are not to be regarded as precise measures of effectiveness. Furthermore, the number of licensed drivers was used to compute a measure of effectiveness. This data was obtained from the annual Highway Statistics Report, published by the Federal Highway Administration (FHWA, 2008). However, these counts are known to have errors, and as a result, this should be kept in mind when interpreting these results (IIHS, 2006). Finally, it is possible that teen drivers were hesitant to report their true travel exposure in their trip logs, particularly if their travel violated the restrictions of their GDL program. This would lower exposure for teens, thus raise the crash/fatality rate derived from that metric. This may also be a factor in the results.

7.5 Conclusion

This study investigated the effectiveness of GDL in reducing the travel exposure-normalized crash and fatality rates on a national scale. The travel exposure of teen drivers was found to be lower in the GDL period compared to the pre-GDL period. As a result, effectiveness measures derived from these metrics revealed that teen/adult ratios for crash per VMT and fatalities per PMT were higher in the GDL period for 16 and 17 year old drivers. 17 year old drivers were shown to have the largest increase in their crash and fatality rates relative to adult drivers from a travel exposure perspective. Furthermore, night-time driving occurred less frequently for teen drivers after GDL implementation. However, the teen/adult crash and fatality rates for 16 and 17 year old drivers from midnight–5:59a.m. were shown to be higher in the GDL period when normalized by travel exposure. These results have suggested that restricting teen driving through GDL has indeed reduced the exposure of teen drivers to complicated driving scenarios but may be less effective at preparing teen drivers for the more difficult driving environments when they are presented, particularly after the restrictions are lifted.

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8. Conclusions

8.1 Teen Drivers

The crash risks associated with novice drivers have always been elevated when compared to more experienced drivers (Gregersen et al., 2003; Mayhew et al., 2003). Furthermore, the fatality risks for teen drivers have remained a paramount issue in traffic safety research. Teen drivers account for 14.6% of all fatalities in motor vehicle crashes, yet, according to the Federal Highway Administration, teen drivers only account for 4.8% of all licensed drivers (FHWA, 2008). Furthermore, the Insurance Institute for Highway Safety (IIHS) reports that motor vehicle crashes are the leading cause of death for all persons aged 13-19 years old (IIHS, 2009). This is all despite a decline in overall teen fatalities over the last two decades.

Graduated driver licensing (GDL) programs have been widely enacted to reduce the crash involvement of teenagers. The theory behind GDL programs is that driving skills are acquired through practice and experience. Furthermore, novice drivers need time to accumulate the experiences necessary to develop their driving skills. In general, GDL programs within the United States have been reported to be effective at reducing the crash and fatality rates for teen drivers (Shope et al., 2003; Simpson, 2003; Williams, 2006).

The goal of this dissertation was to 1) evaluate the effectiveness of the New Jersey GDL program in reducing the teen driver crash risk, fatality risk, and violation risk, 2) evaluate the effectiveness of a plea-agreement ban on teen driver crash and violation rates, 3) identify the residual teen driver crash causing factors and behaviors, and 4) identify the relationship between changes in teen driver travel exposure and teen driver crash and fatality counts.

8.2 Data Sources

This dissertation has used a number of different data sources to establish the effectiveness of GDL programs. The Fatal Automotive Reporting System (FARS) dataset frequently was used to evaluate the fatality rates associated with the implementation of GDL. To study the effectiveness of GDL in New Jersey the NJCRASH dataset, which is a collection of all police reported crashes in New Jersey from 1997-2009, was used. However, this thesis also utilized more novel datasets including the New Jersey Motor Vehicle Commission (NJ MVC) violations dataset. This allowed us to compare the violation rates and types for teen drivers before and after GDL implementation. Also, the NJ MVC dataset allowed us to investigate changes in the violation patterns following a ban on plea-agreements for teen drivers in New Jersey. Another unique approach utilized the National Motor Vehicle Crash Causation Survey (NMVCCS) which allowed us to identify the factors that contribute to teen driver crashes after the implementation of GDL in the United States. Furthermore, it was possible to determine the changes in the travel exposure-based effectiveness of GDL in the United States by using the National Household Travel Surveys from 1995 and 2009. This provided valuable insight into the reasons for reductions in teen driver crashes and fatalities. The utilization of these novel approaches and datasets has provided additional context and perspective on the effectiveness of GDL in the United States that had previously not been reported.

8.3 The Effectiveness of the New Jersey GDL Program

The New Jersey GDL program is considered to be one of the most progressive and stringent in the United States. Furthermore, the availability of data and the unique components of the New Jersey GDL system allowed for insightful and unique analysis.

The NJCRASH database contains 13 years of data which allowed us to investigate the long range effects of the GDL system. Also, the analysis presented in this thesis was able to include more years of data and address data quality issues that had not been part a previous study on the effectiveness of the New Jersey GDL system {Williams, 2010 #340}. The analysis in this thesis included the use of a 12-county subset of New Jersey to determine the crash rate effectiveness measures. These counties were shown to be of better and more consistent data quality and, therefore, an analysis of this subset was determined to be more reliable and representative of the New Jersey experience.

Overall, the New Jersey GDL program showed similar effectiveness when compared to measures that had previously been published regarding other GDL programs. It had previously been shown that the crash rates, e.g. crashes per year or crashes per capita, in the first year of restricted, unsupervised driving have been reduced by 14-24%. However, only a 3-6% reduction in crash rates in the first year of unrestricted, unsupervised driving has been identified (Foss et al., 2001; Rice et al., 2004; Fohr et al., 2005; Kirley et al., 2008). This indicates that the improvements in teen crash rates seen with GDL are most pronounced while the drivers are subject to the regulations of GDL. Our analysis of the New Jersey GDL system expressed similar results. It found that the per capita crash rates for teen drivers in the first year of restricted, unsupervised driving have been reduced by 19.8% after GDL implementation. Also, teen drivers in the first year of unrestricted, unsupervised driving had a per capita crash rate that was 5.3% lower after GDL implementation. The large difference between the New Jersey experience and that of other GDL programs in the United States is that the minimum age for each licensure stage is generally one year later than for most other programs. Therefore, even though the effectiveness measures for New Jersey are comparable for ages in the different stages of licensure, the crash rates are delayed by one year when compared to less stringent GDL programs. Furthermore, this may also be the expected result if other states were to adopt the regulations of the STANDUP Act. The New Jersey GDL program meets or exceeds all of the requirements of the STANDUP Act. New Jersey and Washington, D.C. are the only two jurisdictions in the United States that meet these stringent requirements. As a result, comparing the effectiveness of the New Jersey GDL system to other, less strict programs in the United States offered perspective on any benefits that may result from other States enhancing their regulations to meet those outlined in the STANDUP Act.

An analysis of the New Jersey GDL program offered interesting insight into the types and rate of teen violations following the implementation of GDL as well. There has been limited research on the effect of GDL on teen violation rates in the literature. Also, for the studies that have been conducted, it was often done with a limited number of years and failed to correct the teen driver violation rates for the overall trends seen for drivers of other ages. The study presented in this thesis used data that spanned 11 years and used appropriate techniques to identify the statistical significance of changes in the violation rates while accounting for outside factors, i.e. adult driver violation trends. It was found that the rate of teen driver violations was lower after GDL implementation for those who were subject to the regulations of GDL, i.e. 16 and 17 year old drivers. However, older teen drivers, i.e. 19 and 20 year olds drivers, had higher point-carrying violation rates than their pre-GDL peers. Furthermore, it was found that the types of violations did not change as a result of GDL regulations.

On September 17, 2008, the Attorney General of New Jersey instituted a ban on plea-agreements for GDL drivers in the state. This provided a unique opportunity to investigate the effects of a single regulation. Even though many studies have cited reductions in rate of crashes and fatalities for teen drivers after GDL implementation, it is difficult to determine which of the regulations have been most effective. This is because the regulations are often implemented as a total package. Our analysis of the effect of the plea agreement ban included an investigation into changes in the rate of violations and crashes as well as changes in the rate of driver interventions. This is the first study to perform an analysis of this kind. It was found that the rate of violations was less for 16 and 17 year old drivers after the plea agreement ban. However, the rate of point-carrying violations increased and the rate of zero-point carrying violations decreased after the ban was instituted. Furthermore, the rate of driver interventions, i.e. point accumulation warning notices and PDP driver improvement classes, following the accumulation of point-carrying violations were found to increase for 16 and 17 year old drivers after the ban. This indicates that teen drivers are no longer able to avoid the built-in penalties associated with the accumulation of violation points by pleading to zero-point violations.

8.4 Identifying the Sources of Crash Rate Reductions

While many studies have noted reductions in the per capita or per licensed driver crash and fatality rates for teen drivers after GDL implementation, the reasons for these reductions have largely been unknown. Our analysis of the residual crash factors for teen drivers investigated the crash causation factors that remain for teen drivers in the United States after GDL implementation. An analysis of this nature had never been performed before. It was found that the reasons that teen drivers have crashes are the same as they were before the implementation of GDL. Teen drivers are still prone to intra-vehicle distractions and inappropriate driving. Also, they still have higher rates of control loss and road departure crashes when compared to adult drivers.

This dissertation and previous research has identified that the traditional measures of effectiveness, i.e. per capita and per licensed driver crash rates, had shown GDL to be effective at reducing teen crashes. Many previous studies have cited this finding as evidence that GDL was thereby producing better teen drivers. Our analysis has shown, however, that the reasons for teen driver crashes have not changed as a result of GDL implementation. As a result, we chose to pursue the hypothesis that GDL was not producing better drivers, but rather, it was simply reducing their travel exposure. An analysis of the travel exposure based crash and fatality rates of teen drivers before and after GDL implementation had never been conducted. This was most likely because age-specific measures of travel exposure are difficult to obtain. However, with the release of the 2009 National Household Travel Survey, we were able to account for changes in the travel exposure of teen drivers before and after GDL implementation. Our analysis found that the VMT normalized crash rates of 16 and 17 year old drivers in the United States have increased relative to that of adults after GDL implementation. We speculate that teen drivers may actually be shielded from accumulating the skills needed to address the complicated driving environments that the GDL regulations limit exposure to, i.e. night time driving and passenger restrictions. This is supported by the finding that the increases in crash and fatality rates for 17 year old drivers (the minimum age at which most states lift GDL restrictions) were higher than for any other teen age group, relative to adult drivers. Also, it was found that teen driving at night has become more dangerous for teens who are under GDL regulation or recently graduated from the program. This was shown by the large increases in the travel exposure-based fatality rates in the midnight-5:59a.m. time period for 16 and 17 year old drivers when compared to adult drivers.

8.5 Overall Implications and contributions

This dissertation has presented novel approaches and insight into the effectiveness of GDL in the United States. The results of these studies have suggested that to identify the benefits of GDL, it is necessary to define what the desired benefit is. If GDL effectiveness is defined by its ability to reduce the number of teen driver crashes and fatalities, than it appears to have been successful. However, if GDL effectiveness is to be measured in its ability to change teen driver behaviors, it appears that it has not been as successful. It has been shown that the factors that led to teen driver crashes before GDL are the same factors that led to crashes after GDL implementation. Furthermore, the reductions in the number of crashes and fatalities are shown to be associated with reductions in travel exposure for teen drivers. This dissertation has reaffirmed that the teen driver crash risk remains a problem after GDL implementation. The results and discussion presented may serve as a foundation for further enhancement and understanding of current GDL regulations and how to address the issue of reducing the teen crash risk.

8.6 References

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Appendix A: Efforts to Correct Data Quality Issues in NJCRASH

1. Background

This report will investigate the NJCRASH database as a suitable data source for evaluating GDL effectiveness.

NJCRASH, provided by the New Jersey Department of Transportation (NJDOT), a collection of all police reported crashes in New Jersey from 1997-2009. All of the data is available through the NJDOT website and can be downloaded for analysis (NJDOT, 2009). Two separate formats for recording and reporting the data have been used in this time period. For crashes occurring in 1997-2000, the information is available for download as a single table for each of the 21 counties in New Jersey. Starting in 2001, the data format was changed to a relational format. The newer format is organized as separate tables for the accident, vehicles, drivers, occupants, and pedestrians. These individual tables contain relatable fields which allow the data to be merged easily.

While the two formats (1997-2000 and 2001-2009) are designed to largely provide the same information, they differ in the number of data elements. As detailed in this report, our analysis of the 1997-2000 dataset has revealed a number of data quality problems, not seen in the 2001-2009 format. However, some of the problems were present in both formats. Our efforts to correct these problems are outlined in this report.

1.1 NJCRASH 1997-2000 Data Format

The NJCRASH 1997-2000 data format was available for public download from the NJDOT website as large text files. All fields were comma delimited. The 1997 file was missing two data elements, the SRI and SRI milepost, which were available for the 1998-2000 data. The SAS statistical software was used to perform the data importing and all subsequent analyses (SAS, SAS Institute inc., Cary NC).

Each record in the 1997-2000 data corresponds to one page of the 1997-2000 NJTR-1 police crash report. Each NJTR-1 page, at that time, could only hold information for two vehicles and five occupants. Likewise, each NJCRASH record only holds information for two vehicles and five occupants. For crashes with more than five occupants and/or more than two vehicles, a second record was required. Crash records that pertained to the same crash shared a unique case identifier, but were labeled with a different continuation "page" variable.

The 1997-2000 data format did not come in separate tables for accident, vehicle, and occupant information like the 2001-2009 format. To facilitate the analysis of the 1997-2000 dataset, relatable tables were created for each accident, vehicle, and occupant record. This included finding all "pages" for each crash and extracting the appropriate data from each. Each vehicle was numbered based on its assigned "vehicle number" value. Each occupant was numbered based on the order in which they were read from the importing scheme but the appropriate vehicle number was retained for each. If a record in the occupant table pertained to a pedestrian or a bicyclist, the vehicle number was listed as a "P" or a "B," respectively. If all variables pertaining to a particular vehicle or occupant record had a value of "0," it was assumed that this meant there was no vehicle or occupant and the record was deleted. The occupant and vehicle tables were relatable to the accident table based on the case identifier. The vehicle and occupant tables were relatable based on the case identifier and the vehicle number, as shown in Figure 31.

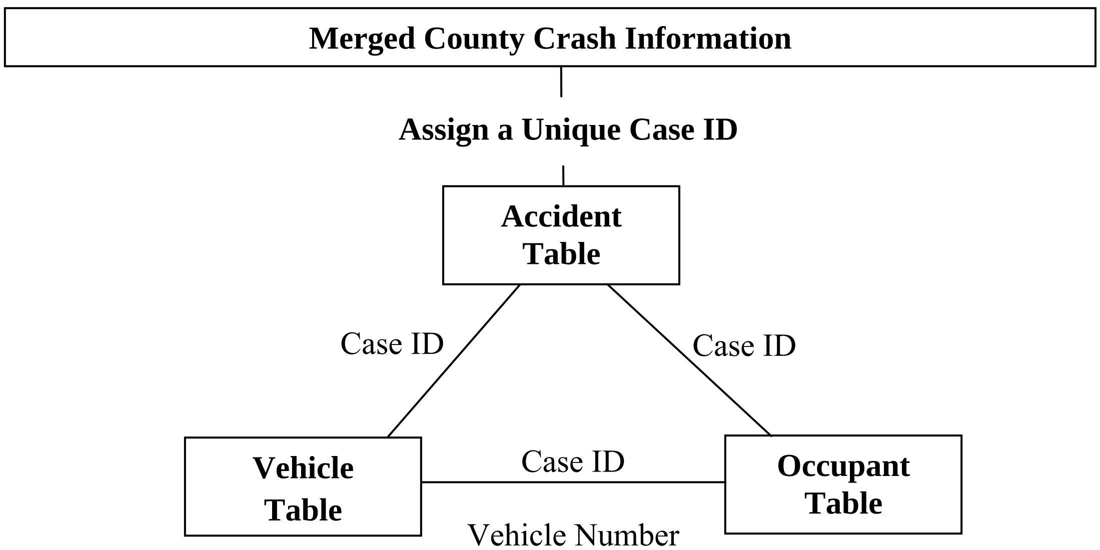

Figure 31. Schematic of the new relational database structure for the 1997-2000 dataset.

1.1.1 Data Quality Verification

The NJCRASH data for the 1997-2000 formats has several known problems, but many of them have been corrected as outlined in this report. Each approach taken to repair inconsistencies or to identify problems with this data is outlined in this section.

1.1.2 Duplicate Records

Many of the 1997-2000 crash records had been entered into the database more than once. Two approaches were used to identify these duplicate records. First, each crash has a unique case identifier. If there were multiple records with the same case identifier, only the last record was kept. It was assumed that the last record would be the most up-to-date. Secondly, cases with different case identifiers, but the same crash data were identified. The records were sorted by county, department case number, crash date, and crash time. If multiple cases matched in these fields, a sampling of the other data elements was taken to identify instances where the other data elements were also the same. For cases where all sampled fields contained the same information, only the last record was kept. However, many matched records contained mostly the same information with the exception of blank fields. In these cases, only the case with the most complete fields was kept. The 2001-2009 files were not found to have any duplicate records. The number of imported records and the number of duplicate records are given in Figure 32 for both NJCRASH formats.

The 1997-2000 format often had more than one record for a given crash. This occurred when there were more than two vehicles or more than five occupants involved in the crash, which is the most that a single record can hold. As a result, the number of imported records less the number of duplicate records does not equal the number of crashes, as shown in Figure 32. Also, the 2001-2009 files did not have any duplicates in any case year and had only one imported record per crash. That is why the number of imported records exactly equals the number of crashes.

After performing these steps, it was assumed that the majority of duplicate records were removed. It is possible that some duplicate records exist, but because of missing data fields, it was not possible to identify these cases with certainty. However, it is thought that there are only a minimal number of duplicate records remaining in the dataset and as a result, any affect on subsequent analyses would be negligible.

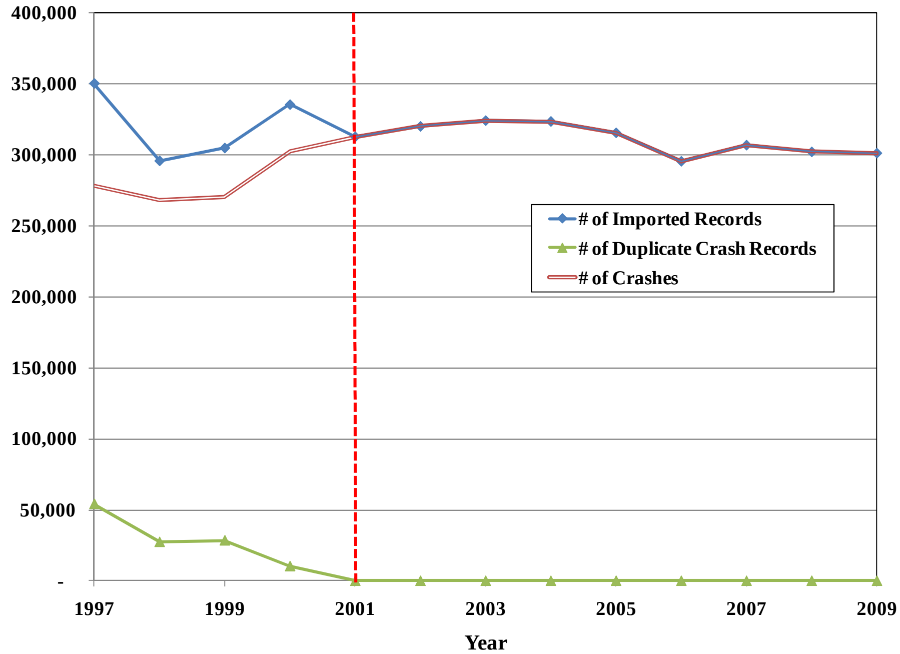

Figure 32. The distribution of the imported records, the number of duplicate records, and the resulting number of crash records for NJCRASH 1997-2009.

Table 33. The number of imported records, duplicate records, and total number of crashes for the NJCRASH 1997-2009 database.

	1997	1998	1999	2000	2001-2009
# of Imported Records	350,097	295,804	304,801	335,267	2,801,329
# of Duplicates	54,252	27,449	28,490	10,325	0
# of Crashes	278,115	268,355	270,469	302,680	2,801,329

1.1.3 Records by County

We next examined the number of crashes per year for sudden step changes. A step change could indicate data entry errors in the database. Note that the number of crashes vs. time from the 2001-2009 files was much smoother than the number of crashes vs. time from 1997-2000. This suggested that the data entry was more consistent from 2001-2009. The one exception was in 2006. This happened to be the year that the NJTR-1 police crash report form was updated. In 2006, the number of crashes suddenly dipped. It was unknown if this was related to difficulties in the switching to the new NJTR-1 format. As shown in Figure 32, the number of crashes in New Jersey from 1997-2009 did not appear to follow a particular trend.

To better understand these patterns, we next examined the number of annual crashes by county. Our hypothesis was that if there were data entry problems, they might be county specific. Figure 33 shows the same inconsistent trends for crash rates by county as were seen for annual crash distributions for the entire state. However, there were some interesting results presented for several counties. Specifically, Essex County showed large variations in the number of crashes over the 12 year period. Furthermore, this county alone accounted for 11% of all crashes over this period, thus having a considerable effect on the crash rate for the entire state. Most of the counties showed relatively constant or increasing crash rates with the exception of Essex, Bergen, and Hudson Counties. Almost all counties showed a dip in crashes in 1998 and 1999; this was also shown in Figure 32. It was unknown whether this was the result of a real-world reduction in crash rate. However, it is unlikely that such large swings in the number of crashes would occur in all counties for these years, suggesting that it is more likely that that there were problems associated with the data collection and reporting.

The inconsistencies in crash rates by county and statewide are a concern, but if reasonable assumptions are applied, their effect can be minimized. If it is assumed that the distribution of crash characteristics (e.g. driver ages, number of vehicles, seat belt use, etc…) is the same for the known and missing crashes, it may be possible to use an induced exposure metric to account for these missing cases. Induced exposure involves normalizing by a population within the same dataset that is assumed to be exposed to the same changes in driving environment. For example, if it was assumed that the percentage of teen drivers and adult drivers were consistent within the known and missing cases, it would be possible to divide one population by the other to cancel out the effects of the missing cases.

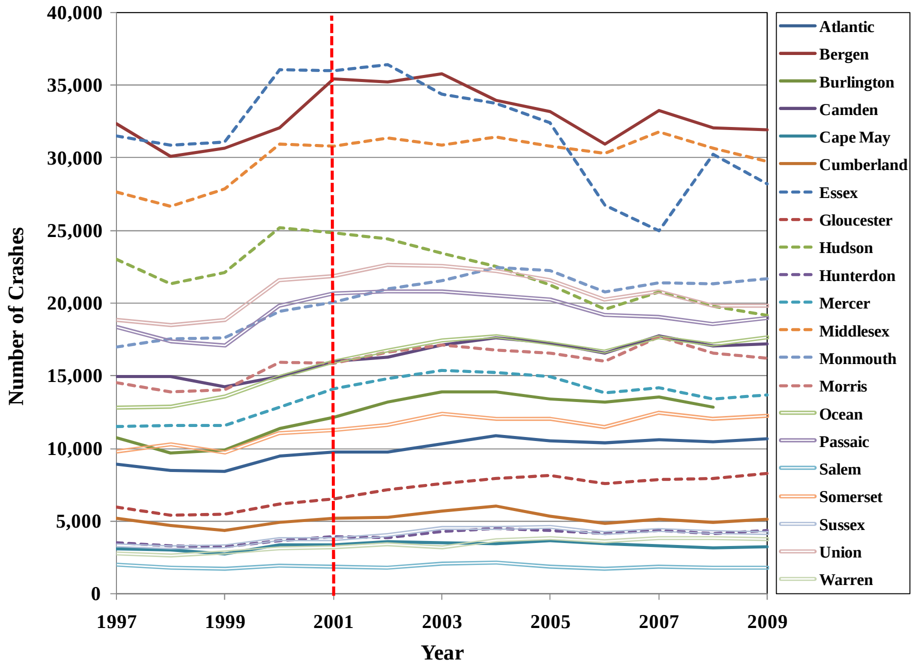

Figure 33. The distribution of records crashes by county for NJCRASH 1997-2009.

1.1.4 The Occupant 4 Issue

The age of occupant 4 is systematically in error for the 1997-2000 files. For the 1997-2000 format, a maximum of five occupants could be contained in a single record. An issue existed that was unique to the age of the fourth occupant in each record. For every record, the age of occupant 4 was the same as occupant 1, as shown in Table 34. However, the other occupant information (e.g. gender, restraint use, etc…) was not always the same. In fact, many occupant 4 records contained no occupant information other than age. Furthermore, when no occupant 4 age was given, no age was given for occupant 1 either. This indicates a data entry problem. This also raised concern about the potential to affect the reporting of driver ages. Having correct driver ages is important to ensure an accurate analysis of teen drivers. It was found that persons listed as occupant 4 only account for 2% of all occupants and 3% of all drivers. However, because it was known that the age of occupant 4 is always the same as occupant 1, it was assumed that the age of a driver listed as occupant 4 was incorrect.

Table 34. A comparison of occupant 4 age and occupant 1 age, the number of records without occupant 4 data, the number of records with no occupant 4 data other than age, and the number of records with occupant 4 data for NJCRASH 1997-2000.

	1997	1998	1999	2000
Occupant 4 age = Occupant 1 age	**350,097**	**295,804**	**304,767**	**335,267**
No Occupant 4 Information	195,091	62,369	55,525	61,574
No Occupant 4 Information Other than Age	96,265	183,644	199,775	219,513
Occupant 4 Information Available	58,741	49,791	49,467	54,180

1.1.5 Crash Case Year

The crash date is listed in the accident table for each crash. From this, it was possible to determine the year in which the crash occurred. It was assumed that all crashes within a given case year should have crash dates within that year. However, this was found not to be true for all crashes as shown in Table 35. Fortunately, it was found that only a small fraction of all cases had given crash years that were different than case year it was listed in. However, cases where the case year differed from the reported crash year were removed to ensure only the cases with the correct crash year were included.

Table 35. The distribution of reported crash years as they compare to the case year file they are listed in for NJCRASH 1997-2009.

	1997	1998	1999	2000	% of all Crashes	2001-2009	%of all Crashes
Total Crashes	278,115	268,355	270,469	302,680	100.0%	2,801,329	100.0%
Crash Year = Case Year	274,020	266,294	266,414	300,233	98.9%	2,801,329	100.0%
Case Year +/- 1 year	1,472	1,590	2,534	2,157	0.7%	0	0.0%
Case Year > +/- 1 Year	77	104	135	0	<0.1%	0	0.0%
Crash Year Missing	2,546	367	1,386	290	0.4%	0	0.0%

1.1.6 Injury and Fatality Counts

The NJCRASH dataset stores occupant injury information in a field called "Physical Status." A check on the physical status field given for each occupant was performed to ensure that the formatting was correct. The variables for this field should have contained a value of 0-4 (0- Unknown, 1- Killed, 2- Incapacitated, 3- Moderate Injury, 4- Complaint of Pain). Table 36 shows that there were very few errors in this field for the 1997-2000 dataset and the 2001-2009 dataset. Note that the total missing cases for the 2001-2009 dataset were much larger than for the 1997-2001 dataset. It was assumed that if 2001-2009 format provided no value for this field, it was because the occupant was not injured, contrary to the 1997-2000 format which would often give a "0" for uninjured occupants. However, the 1997-2000 dataset did contain a large number of missing values as well. Again it was assumed that these occupants were not injured.

Separate from the physical status field for each occupant, there were also "Total Killed" and "Total Injured" fields in each accident record that sum the number of injured persons and fatalities in a particular crash. This provided two methods of accounting for injuries and fatalities in New Jersey crashes. However, as shown in Table 38, the number of "Total Killed" and the number of "Total Injured" did not agree with the tabulated "Physical Status" fatalities and injuries, respectively. It was found that the cases where the Total Injured and Total killed in the accident table did not match the total numbered of injured and killed occupants in the occupant table were cases with continuation pages. In some cases, the total number of killed or injured occupants in a crash was recorded on each continuation page corresponding to that crash. As a result, there was a significant over estimation of injuries and fatalities using these fields as compared to the physical status field. Also, it was shown in Table 38 that the number of fatalities from both fields do not agree with the number of fatalities reported by the NJDOT reports (NJSP, 2009). This lack of consistency makes it difficult to use this data as a source for fatality rates in subsequent GDL effectiveness calculations.

Table 36. The accuracy of the formatting and availability for the "Physical Status" field in the NJCRASH 1997-2009 database.

	1997	1998	1999	2000	2001-2009
Physical Status = 0-4	649,168	637,494	588,393	708,083	954,196
Miscoded	8	0	10	0	0
Missing	36,077	35,070	40,377	32,472	5,912,201
Total	685,253	672,564	628,780	740,555	6,866,397

Table 37. Number of injuries from the "Physical Status" field and the number of injuries reported from the "Total Injured" field in the NJCRASH 1997-2009 database.

	1997	1998	1999	2000	2001-2009
Physical Status Injuries	126,419	112,214	93,199	116,402	892,009
Total Injured Field	223,483	201,685	156,252	210,652	947,815

Table 38. Number of fatalities from the "Physical Status" field and the number of fatalities reported from the "Total Killed" field in the NJCRASH 1997-2009 database as compared to the number of NJDOT Report fatalities.

	1997	1998	1999	2000	2001-2009
Physical Status Deaths	2,804	1064	670	1,599	6192
Total Killed Field	4,296	1,552	956	1,802	6222
NJDOT Reports	*N/A*	*761*	*725*	*723*	5801*

**-No NJDOT report available for 2009*

1.1.7 Driver and Vehicle Counts

For the 1997-2000 dataset, a table was constructed with a separate record for each vehicle. Also, an occupant table was constructed with a separate record for each occupant. Both tables included information regarding the driver. For both the 1997-2000 format and the 2001-2009 format, the vehicle table contained information taken directly from the driver license of the driver in each vehicle including the date of birth, licensing state, and driver gender. The occupant table provided the age, physical status, gender, and restraint use of all occupants, including the driver. However, for the 1997-2000 format there were instances where there was driver information provided in the vehicle table, but no corresponding record existed in the occupant table. In these circumstances, a new occupant record was created for the driver of the vehicle in the occupant table. Also, if a duplicate record existed for a driver in a given vehicle, only the last record was kept.

To check the quality of vehicle data included in the analysis, the number of drivers and the number of vehicles were compared for both formats. The assumption was that there should be an equal number of drivers and vehicles. Also, a separate check was performed to ensure that there was only one driver per vehicle. Only crashes that were listed as occurring in the case year were included. Table 39 shows, for the 1997-2000 dataset, 14% of vehicles had no driver listed and 1% of the vehicles had more than one driver listed. The 2001-2009 dataset showed a very similar distribution where 17% of vehicles had no driver and 0.4% of vehicles with more than one driver.

If the number of drivers was assumed to be equal to the number of vehicles, it would be possible to extrapolate the actual number of drivers by again assuming that the distribution of drivers in missing cases were the same as the distribution of drivers in the known cases. This would be particularly useful for determining the number of missing drivers at a given age. Also, by assuming that the missing driver counts were evenly distributed over all ages, it was possible to use the induced exposure approach to cancel out the errors associated with the missing cases.

Table 39. The number of vehicles, the number of drivers, and distribution of drivers within the vehicles for the NJCRASH 1997-2009 dataset.

	1997	**1998**	**1999**	**2000**	**% of All Vehicles**		**2001-2009**	**% of All Vehicles**
Number of Drivers	473,165	464,921	437,940	514,825	-		4,434,843	100.0%
All Vehicles	546,397	534,494	508,629	595,017	100.0%		5,269,449	83.4%
Vehicles with one Driver	463,439	452,937	429,951	504,382	84.7%		4,92,309	83.4%
Vehicles without a driver	78,195	75,672	74,747	85,501	14.4%		856,180	16.3%
Vehicles with more than one driver	4,763	5,885	3,931	5,134	1.0%		20,960	0.4%
Drivers with no vehicle	*2*	*0*	*4*	*0*	-		*0*	*0.0%*

1.1.8 Crash Date and Date of Birth

The driver date of birth (DOB) was given in the vehicle table. The crash date was given in the accident table. The validity of these dates was checked. The dates given in the data files for the 1997-2000 dataset were presented in a number of different formats (e.g. mm/dd/yyyy, mm/dd/yy, mmddyy, or mmddyyyy). Problems associated with irregular dates were also discovered. These were cases where the month given was larger than 12 or the day given was larger than 31. All formats were converted to a standard mmddyyyy format for both the crash date and the driver

DOB. The existence of incomplete records was a reoccurring issue in both formats, including records with missing driver DOB, crash dates, and given ages. The distribution of these driver records are given in Table 40.

Table 40. Distribution of missing crash dates, driver date of birth, and given driver age for NJCRASH 1997-2009.

	1997	1998	1999	2000	% of all Drivers	2001-2009	% of all Drivers
Total Drivers	**473,165**	**464,921**	**437,940**	**514,825**	**100%**	**4,434,843**	**100%**
Crash Date Missing	134	287	433	7,764	0%	0	0%
Driver DOB Missing	3,915	7,042	6,334	11,027	1%	443,951	10%
No Calculated Age	4,040	7,302	6,745	13,065	2%	443,951	10%
Given Driver Age Missing	184,695	64,139	56,043	53,153	19%	447,452	10%

1.1.9 Driver Age

It is important that the driver age in a given vehicle be correct in order to determine the effect of the GDL regulations. Using the date of birth and crash date, it was possible to calculate an age for each driver. Also, age was given for records in the occupant table. After reformatting the dates in the 1997-2000 format records, the ages determined by the crash date and driver DOB were compared with the given age in the occupant table. The same comparison was performed on the 2001-2009 formatted data as well. Only crashes that were listed as occurring in the case year were included. Records where the driver age was given or the driver age could be calculated were referred to as “Age Available” cases. In 63% of age available cases the calculated age matched the given age for the 1997-2000 format and 84% of drivers in the 2001-2009 format. In another 8%, the calculated age was within one year of the recorded age for the 1997-2000 format drivers and 5% of 2001-2009 format drivers. However, 4% of all calculated and given ages differed by more than 10 years for the 1997-2000 format data but only 1% of the 2001-2009 records. 22% of all age available drivers were not assigned an age in the occupant table or an age could not be calculated for 1997-2000 format drivers and 5% of 2001-2009 format drivers. For cases where the age was not provided in the occupant table, an age was assigned based on the calculated age. For cases where an age could not be calculated, the age from the occupant table was used. In the end, for 93% of all 1997-2000 format drivers and 97% of all 2001-2009 format drivers, there was sufficient data to either calculate the driver age or the driver age was given, as shown in Table 41.

The calculated age was considered to be more accurate based on the assumption that the driver DOB would be copied directly from the driver's. Therefore, when possible, the calculated age was used as the driver age. However, when this was not possible because either the driver DOB or the crash date was not provided, the given age was used. For cases in which the DOB or crash date were miscoded, the given age was retained as opposed to the calculated age. Figure 34 shows the distribution of drivers and the number of drivers with a known age for both NJCRASH formats. The distribution of drivers between formats was qualitatively similar to the distribution of crashes between formats as shown in Figure 32. Again, it was not known if the dip in 1998 and 1999 was representative of a real-world drop in the number of drivers involved in crashes, however it is more likely that it was an issue associated with data collection and reporting.

Table 41. The distribution of given and calculated and given ages for drivers based on the NJCRASH 1997-2009 database.

	1997	1998	1999	2000	% of Total Drivers	% of Age Available	% of Total Drivers 2001-2009
Total Drivers	473,165	464,921	437,940	514,825	**100.0%**	**-**	**100.0%**
No Age Available	35,777	30,478	31,720	26,367	**6.6%**	**-**	**3.0%**
Total Drivers with Age Available	437,388	434,443	406,220	488,458	**93.4%**	**-**	**97.0%**
Matched Ages	200,337	285,568	273,211	346,298	**58.5%**	**62.6%**	**84.9%**
Different Given and Calculated Ages	237,051	148,875	133,009	142,160	**35.0%**	**37.4%**	**12.2%**
+/- 1 Year	25,059	36,507	32,843	39,796	**7.1%**	**7.6%**	**4.3%**
+/- 2-10 Years	13,847	20,929	17,576	20,039	**3.8%**	**4.1%**	**1.9%**
+/- > 10 Years	10,827	20,708	20,639	18,619	**3.7%**	**4.0%**	**0.9%**
No Given / Calc Age	187,318	70,731	61,951	63,706	**20.3%**	**21.7%**	**5.1%**

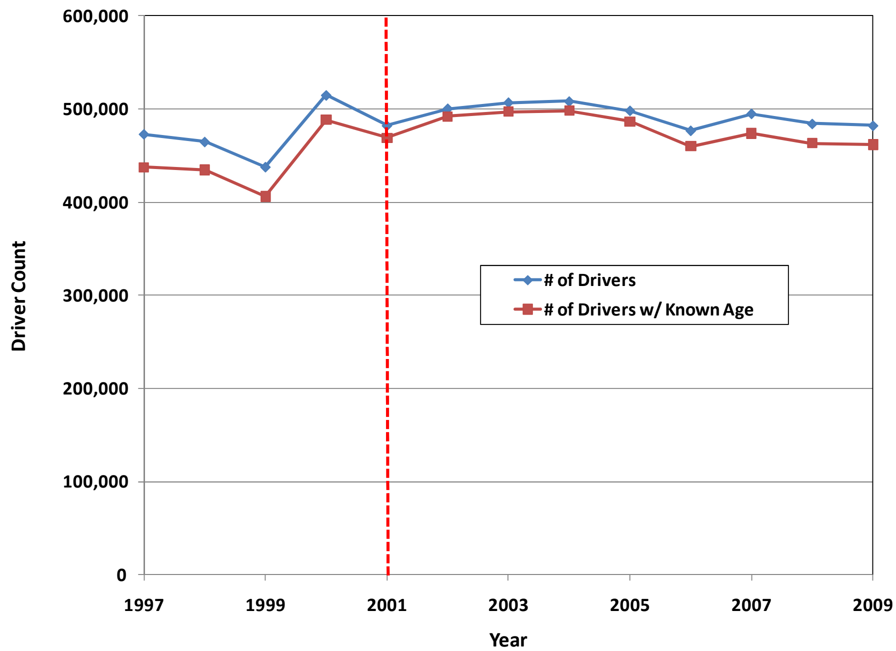

Figure 34. The total number of drivers and the total number of drivers with a known or calculated age for NJCRASH 1997-2009.

2. Conclusions

The NJCRASH datasets has several errors in formatting and completeness. The efforts outlined in this report have significantly reduced these errors. Following these improvements, this data set is usable for a number of different analytical purposes. However, the NJCRASH data, particularly the 1997-2000 format, has limitations and must be used carefully. For example, the issues associated with the reporting of fatalities and injuries need to be addressed before this data can be used for an analysis of fatal or injurious crashes. On the other hand, the use of the induced exposure normalization method under the assumption of equal distribution of crash characteristics in both the missing and known cases may help to negate issues associated with missing records.

3. References

NJDOT (2009). "State of New Jersey Department of Transportation: Crash Records." Retrieved June 25, 2009, from http://www.state.nj.us/transportation/refdata/accident/.

NJSP (2009). "Crime Reports and Statistics." Retrieved June 25, 2009, from http://www.njsp.org/info/stats.html#fatalacc.

Appendix B: MVC Dataset Composition

The New Jersey Motor Vehicle Commission (MVC) maintains a dataset that is a census of all recorded events in their system. Events in the system include warning notices for point accumulations, suspension scheduling, traffic violations, and crashes for drivers licensed in the state. We were able to gain access to a semi-sanitized sample of this dataset to be used for analyzing changes in violations for teen drivers. The dataset we obtained was a collection of all events that occurred from January 1, 1986 to March 20, 2010. When received, the dataset was constructed so that a single row of data corresponded to the record of one driver. This included basic driver record information (gender, date of birth, etc…), followed by details corresponding to each event. The details of up to 100 events per driver record were provided. The dataset is not a collection of all driver records in the state, but rather a collection of all events that occurred after January 1, 1986. For example, if a driver recorded no events after this date, there would be no record of then in the dataset that was provided to us. This prevented us from using the dataset to create a count of licensed drivers within the state.

We acquired the dataset in two phases. The first dataset, acquired from Rutgers University, consisted of events occurring between January 1, 1986 and March 20, 2007. A second dataset was obtained to supplement the original dataset. This supplemental dataset contained driver records for drivers who had recorded events from January 1, 2007-March 31, 2010. As a result, there were duplicate records when the two datasets were combined. For all instances with duplicate driver records, the supplemental data was retained under the assumption that it was the most up-to-date. This applicability of this method was confirmed through conversations with New Jersey MVC contacts.

Dataset Restructuring

A restructuring of the dataset was undertaken to facilitate analysis. The dataset was reformatted so that a separate record was created for each event for each driver. As part of this process, the Driver License Number was replaced with a random driver record number which was unique to that driver record but could not be used to identify the driver. The resulting event records consisted of both the basic driver demographic information as well as information for each event. This is illustrated in Figure 35. This reformatting served multiple purposes. First, it significantly reduced the size of dataset by reducing the number of columns of data from 4,920 to 20. Secondly, it simplified our analysis of individual events or event types. A list of the included variables in the MVC dataset is included in Table 49. Furthermore, we were able to sanitize the dataset so that no personal identifiers were included in the final dataset that was used for our analyses. The original dataset, which contained any personal information pertaining to the drivers, was kept in a separate, secure location.

Figure 35. Restructuring of the MVC dataset.

Record ID #	Event #1	Event #2	Event #3	Event #4	…
1	Violation	Accident	Violation	Fee	…
2	Violation	Fee	Information	Information	…

Record ID #	Event #	Event type
1	1	Violation
1	2	Accident
1	3	Violation
1	4	Fee
2	…	…

The dataset composition was compared to those reported in Carnegie et al (2009) to serve as a methodological check. Carnegie et al are the only other group to use this data in a similar manner and as such, we wanted to ensure that we were applying appropriate analytical methods. However, the Carnegie analysis was only conducted on events that occurred before April 1, 2007 because it was the latest available data at the time. As a result, our corresponding analysis was performed on the same data, prior to the addition of the supplemental data set (2007-2010). The distributions of events by date are provided in Table 42. Distributions by event type are given in Table 43. The distributions of violations (Event Type = ‘V’) and crashes (Event Type = ‘A’) were computed by age and gender and are reported in Table 44 and Table 45, respectively. While the counts for each comparison with the Carnegie report did not match exactly, it was determined that the differences would have a negligible effect in the subsequent analyses and that they were most likely the result of unpublished methodologies employed by Carnegie.

Table 42. Event distributions by event date from the Carnegie et al (2009) analysis and the Virginia Tech analysis of the MVC 1986-2007 data.

	Carnegie et al	Virginia Tech
Pre-1997 or Missing	50,477,639	50,410,423
1997+	44,754,579	45,815,001
Total	**95,232,218**	**96,225,424**

Table 43. Event type distribution by event code for events between 1997-2007 from the Carnegie et al (2009) analysis and the Virginia Tech analysis.

	MVC Field Code	Carnegie et al		Virginia Tech	
Violation	U, Z, V	**13,414,769**	30.0%	**13,639,617**	29.8%
Suspension	G, L, O, R, S	**14,971,377**	33.5%	**15,332,498**	33.5%
Info	B, M, N, W	**9,716,847**	21.7%	**10,062,556**	22.0%
Accident	A	**1,995,304**	4.5%	**1,995,268**	4.4%
Rehab	C, E, I, K, P	**335,058**	0.7%	**341,407**	0.7%
Fee	D, F	**4,321,204**	9.7%	**4,443,655**	9.7%
Total		**44,754,559**	**100.0%**	**45,815,001**	**100.0%**

Table 44. Violation distribution from 1997-2007 from the Carnegie et al (2009) analysis and the Virginia Tech analysis.

	Carnegie et al				Virginia Tech			
	Male	Female	**Total**	% of Total	Male	Female	**Total**	% of Total
16-17	209,300	77,658	**286,958**	4%	210,966	78,413	**289,379**	4%
18-24	1,520,197	609,387	**2,129,584**	27%	1,536,087	617,594	**2,153,681**	27%
25-34	1,431,987	611,967	**2,043,954**	26%	1,447,896	620,492	**2,068,388**	26%
35-44	1,119,736	554,763	**1,674,499**	21%	1,133,426	563,198	**1,696,624**	21%
45-54	678,311	343,354	**1,021,665**	13%	689,375	350,032	**1,039,407**	13%
55-84	306,956	138,803	**445,759**	6%	460,506	209,844	**670,350**	8%
85+	145,431	66,680	**212,111**	3%	6,521	3,311	**9,832**	0%
Total	**5,411,918**	**2,402,612**	**7,814,530**	**100%**	**5,484,777**	**2,442,884**	**7,927,661**	**100%**

Table 45. Accident distribution from 1997-2007 from the Carnegie et al (2009) analysis and the Virginia Tech analysis.

	Carnegie et al				Virginia Tech			
	Male	Female	**Total**	% of Total	Male	Female	**Total**	% of Total
16-17	42,489	36,455	**78,944**	4%	42,560	36,501	**79,061**	4%
18-24	213,083	164,094	**377,177**	19%	213,077	164,096	**377,173**	19%
25-34	230,838	173,082	**403,920**	20%	230,813	173,050	**403,863**	20%
35-44	243,557	185,032	**428,589**	22%	243,591	185,066	**428,657**	22%
45-54	191,612	140,314	**331,926**	17%	191,575	140,279	**331,854**	17%
55-84	208,104	143,873	**351,977**	18%	208,100	143,866	**351,966**	18%
85+	7,252	4,814	**12,066**	1%	7,249	4,896	**12,145**	1%
Total	**1,136,935**	**847,664**	**1,984,599**	**100%**	**1,136,965**	**847,754**	**1,984,719**	**100%**

To further facilitate our analyses, a format file was created to decode the violation codes given in the dataset. Furthermore, it was discovered that multiple event codes may exist to describe the same violation. Therefore, event codes that were discovered to reference the same violation type were combined. It should be noted that for violation events where the offense was amended following a court appearance, it was this amended violation that was reported in the MVC dataset. Unfortunately, there was no record of the original violation provided. A “Violations only” table was created which included all violation events (Event Type = ‘V’) that occurred after January 1, 1997. This table would serve as the source for all subsequent violation analyses.

Crash events were also logged in the MVC dataset. However, after comparing the crash frequency by year from both the MVC dataset and the NJCRSAH dataset, it was found that the MVC largely did not report crashes until 2002. As such, this dataset was not used for a crash analysis.

After our methods were satisfactorily confirmed through a comparison with the results reported by Carnegie et al, we proceeded to perform an analysis of the contents of the combined data set which includes events that occurred from January 1, 1986-March 31, 2010. The distribution of driver license types is given in Table 46, the distribution of event types are given in Table 47, and the date range distribution for each recorded event are given in Table 48. The total dataset contained over 9 million unique driver records resulting in over 110 million recorded events.

Table 46. Distribution of driver license types for the full dataset (MVC 1986-2010).

Driver's License Type		
Auto	7,667,949	79.94%
Identification	1,290,693	13.46%
Commercial Vehicle - A	175,769	1.83%
Commercial Vehicle - B	137,849	1.44%
Commercial Vehicle - C	19,672	0.21%
Auto & Bus	1,512	0.02%
Moped	1,219	0.01%
Agricultural	1,085	0.01%
Unknown	2,183	0.02%
Motorcycle	831	0.01%
Auto, Motorcycle, & Bus 2	611	0.01%
Auto, Bus 2 & Art Vehicle	500	0.01%
Auto, Motorcycle, Bus 1 & Art Vehicle	498	0.01%
Auto, Bus 1 & Art Vehicle	434	0.00%
ID - Handicap	398	0.00%
Auto, Motorcycle, & Bus 1	281	0.00%
ID - Student	89	0.00%
Auto, Motorcycle, Bus 2 & Art Vehicle	83	0.00%
Missing	289,928	3.02%
Total	**9,591,584**	**100.00%**

Table 47. Distribution of recorded event types for the full dataset (MVC 1986-2010).

Event Type		
MEMO ENTRY	18,967,987	17.15%
VIOLATION	18,966,132	17.15%
SUSPENSION ORDER	18,632,449	16.85%
POINT CREDIT	12,956,287	11.72%
SCHEDULED SUSPENSION	8,895,566	8.05%
FEE PAYMENT	7,367,249	6.66%
ACCIDENT	7,144,239	6.46%
RESTORATION	5,888,403	5.33%
INFORMATION	3,831,044	3.46%
ADVISORY NOTICE	3,282,510	2.97%
FEE DUE	2,161,047	1.95%
VIOLATION	810,948	0.73%
SUSPENSION	458,985	0.42%
PROGRAM ACTIVITY	420,678	0.38%
WARMING NOTICE	360,648	0.33%
CONFERENCE	301,460	0.27%
REHAB	49,658	0.04%
REEXAMINATION ACTIVITY	41,679	0.04%
REFERRAL WITH INTERVAL REPORTING	32,545	0.03%
MISSING	56	0.00%
UNKNOWN	19	0.00%
Total	**110,569,589**	**100.00%**

Table 48. Distribution of recorded event date for the full dataset (MVC 1986-2010).

Event Date		
January 1, 1986 – December 31, 1996	62,158,860	56.2%
January 1, 1997 – March 31, 2010	48,410,729	43.8%
Total	**110,569,589**	**100.0%**

References

Carnegie, J. A., K. Ozbay, et al. (2009). "Study of the Effects of Plea Bargaining Motor Vehicle Offenses." New Jersey Department of Transportation. FHWA NJ-2009-018.

Table 49. MVC Dataset variables and event type

Description	SAS Variable	Driver Info	Event Type: Viol. Event	Event Type: Suspension	Event Type: Rehab
Address County	ADR_CNTY	x			
Address City	ADR_CTY	x			
Address State	ADR_ST	x			
Address Street	ADR_STR	x			
Address Zip Code	ADR_ZIP	x			
Comment Field	COMM_STA	x			
Current License Number	CUR_AUTOPIC	x			
Endorsement Flag	ENDR_FLAG	x			
Driver DOB	G_DOB_	x			
Drivers Record Number	DRV_RECORD	x			
License Expiration Year	LIC_EXP_YR_	x			
License Term	LIC_TRM	x			
License - Vehicle Class	LIC_VEH_CLASS	x			
Comment Field	NON_COM_STA	x			
Probation Date	PRB_DT	x			
Restriction Flag	RSTRCT_FLAG	x			
Sex	SEX_CD	x			
SOR Indicator	SOR_IND	x			
Insurance Surcharge Indicator	SURCH_IND	x			
Event Date	EVT_DT		x	x	x
Event Identification Code	EVT_ID_CD		x	x	x
Event Responsibility Code	EVT_RSPY_IND		x	x	x
Event Status Indicator	EVT_STA_IND		x	x	x
Event Type	EVT_TY_IND		x	x	x
Date Posted to System	POST_TME_STMP		x	x	x
Accident Disposition Indicator	ACDT_DISP_IND		x		
Age Event Record	AGE_EVT_REC		x		
Blood Alcohol Percent	BLD_ALCH_CNTNT_PCT		x		
Operating a Commercial Vehicle at the time of DWI	CMV_FLG		x		
Control Sequence Number	CNTRL_SEQ_NUM		x		
Conviction Date	CNVCT_DT		x		
DWI Determined By Indicator	DWI_DTRMND_BY_IND		x		
Driving While Intoxicated Flag	DWI_IND		x		
Fine Amount	FNE_AMT		x		

Description	SAS Variable	Driver Info	Event Type: Viol. Event	Event Type: Suspension	Event Type: Rehab
Operating a HAZMAT Vehicle at the time of DWI	HAZMAT_FLG		x		
License Surrendered Flag	LIC_SUR_FLG		x		
Plea Agreement	PLEA		x		
Points Assessed	PT		x		
Speed	SPD		x		
Speed Limit	SPD_ZONE		x		
Surcharge Count	SURCH_CNT		x		
Within type, what is being affected	SUSP_CD		x		
Violation Status	VIOL_ST		x		
Violation Time	VIOL_TME		x		
MVC Agency that collected fee	SITE_CD		x		
Suspension Detail Begin Timestamp	EFF_TME_STMP_BEG			x	
Suspension Detail End Timestamp	EFF_TME_STMP_END			x	
Event num of allowance	EVT_NUM_ALWNC			x	
Event num of Limitation	EVT_NUM_LIM			x	
Event num of order of suspension	EVT_NUM_ORD			x	
Event num of restoration	EVT_NUM_RSTR			x	
Event num of scheduled suspension	EVT_NUM_SCHD			x	
Date of order of suspension	ORD_DT			x	
Suspension Effective Date	SUSP_EFF_DT			x	
What type of privilege is being affected	SUSP_IND			x	
Date suspension was satisfied	SUSP_SATFN_DT			x	
Suspension Status Indicator	SUSP_STA_IND			x	
Length of suspension	SUSP_TERM			x	
How term is used with other suspensions	SUSP_TERM_CD			x	
Attendance Flag	ATTD_FLG				x
Start Date	DT_STRT				x
Location Code	LOC_CD				x
Number of medical interval reports that have to be submitted each year	MED_INTRVL_PER_YR				x
Total number of reports to be submitted	MED_INTRVL_TOT				x
Monitor date	MNTR_DT				x
Room/Section	ROOM_SECT				x
Start Time	TME_STRT				x

Table 50. Restructured "Violations Only" MVC dataset variables

Description	SAS Variable
Driver Record Number	DRV_RECORD
Date of Birth	G_DOB_
Sex	SEX_CD
License - Vehicle Class	LIC_VEH_CLASS
License Expiration Date	LIC_EXP_YR_
Probation Date	PRB_DT
Event Number	Event
Event Date	Event_DT
Event Restriction	Event_RSTR
Driver Age At Event	Event_Age
Event Type	Event_Type
Event Responsibility Code	RESPONSIB
Violation Points	POINTS
Speed	SPEED
Speed Limit	SPEED_ZONE
Conviction Date	CONVICT_DT
Violation Time	VIOLAT_TM
Plea Agreement	PLEA_AGREE
Fine Amount	FINE_AMT
Event Identification Code	EVT_ID

Appendix C: Using Survey Procedures in SAS

Introduction

Many survey datasets use either stratification and/or clustering in their survey design as a way to ensure that all represented populations are included in the survey and to allow for statistical approaches that account for the sampling design. Clusters are regions or groups from which the sampled data is randomly collected. The strata generally consist of population categories that define the data points being collected. For example, NASS/CDS assigns each crash into one of ten strata. Each of the strata is defined by the characteristics of the crash, such as vehicle type or if it was a fatal crash. In many data collection methods, emphasis is placed on collecting cases that fall into the rare strata categories. However, this means that the selection process can no longer be considered completely random. As a result, case weights are often applied to each data point to create a representative sample based on the inverse likelihood of selecting that data point, or a data point just like it.

Accounting for the stratification and clustering of a dataset is important when making statistical determinations. This is because both clustering and stratification introduce a certain level of variability into the data and therefore, this will affect the variance of population estimates. This variability can be accounted for by utilizing the appropriate statistical techniques. Generally, this is done with the assistance of a statistical software package such as SAS. This appendix provides some basic examples of how to account for stratification and clustering using the SURVEY procedures in SAS.

Example

Research Objective: **What is the relative risk of a teen driver being in a crash while distracted as compared to an adult driver?**

Database: **National Motor Vehicle Crash Causation Survey (NMVCCS)**
SAS Procedures: **PROC SURVEYMEANS & SURVEYFREQ**

Clustering Variable: **PSU**

Stratification Variable: **PSUSTRAT**

Data Step

```
LIBNAME LIBRARY 'c:\nhtsa\nmvccs\';
LIBNAME NMVCCS 'c:\nhtsa\nmvccs\';

OPTION NOCENTER NOFMTERR LS = 256 formdlim="_" PAGESIZE = 500;

Proc Sort data =  NMVCCS.PCA; By PSU SCASEID VEHNO;
Proc Sort data =  NMVCCS.OCC; By PSU SCASEID VEHNO;

Data OCC_PCS_Merge;
      Merge NMVCCS.OCC NMVCCS.PCA;
            By PSU SCASEID VEHNO; Run;

Data age_distraction;
      set OCC_PCS_Merge;

/*------ Find Age Range of Driver */
      if (Ageyear >= 16) and (ageyear <= 18) then Age_range = '16-18';
      if (Ageyear >= 35) and (ageyear <= 55) then Age_range = '35-55';

/*------ Identify Distractions */
      Dist = 'No Distraction';
      if (converse in (2 3 4 5) or        /* Driver Conversing */
            otdract = 1 or                /* Other Distraction */
            extfa = 1)                    /* Extra Factors */
            then Dist = 'Distraction';
run;
```

PROC SURVEYMEANS

The SURVEYMEANS procedure can be used to compute means within a population as well as proportions within a population. With both of these, it is possible to determine the confidence limits of the values by accounting for the stratification and clustering of the dataset. In the example below, the procedure calculates what proportion of crashes involved a distracted driver for teens and adults. When you are looking to calculate a proportion rather than an average, the variable of interest must be included in the class statement as shown below. This defines that variable as a categorical variable rather than a numeric.

```
PROC surveymeans data = age_Distraction Mean clm;
      domain Age_Range; *--- Distraction Distribution for Age Range ---;

         class Dist Age_Range;      *--- To compute ratios, include
                                    categorical variable of interest in CLASS
                                    Statement ---;

         var Dist;                  *--- Variable of interest for ratios ---;

                  strata PSUSTRAT;        *--- Stratification Variable ---;
                  cluster psu;            *--- Clustering Variable ---;
                  weight CASEWGT;         *--- Case weight Variable ---;
      run;
```

The output from the SURVEYMEANS procedure is given below. The output shows the percentage of teen driver and adult driver crashes that involved a distracted driver. The percentage is given in the “Mean” column. This is because the “Dist” variable was given in the class statement. Also, including “Mean” and “CLM” in the data statement instructs SAS to output both the proportion (Mean) and the 95% confidence limits of the proportion (CLM). The 95% confidence limits are calculated through an estimation of the variance using Taylor series linearization.

SURVEYMEANS Output

```
The SURVEYMEANS Procedure

                    Data Summary
Number of Strata                                  12
Number of Clusters                                24
Number of Observations                         19561
Number of Observations Used                    15525
Number of Obs with Nonpositive Weights          4036
Sum of Weights                            5931123.03


              Class Level Information
Class
Variable      Levels    Values

Dist               2    Distraction No Distraction

                                    Statistics
                                                 Std Error
Variable    Level                     Mean         of Mean       95% CL for Mean
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Dist        Distraction           0.285411        0.016583    0.24927930 0.32154232
            No Distraction        0.714589        0.016583    0.67845768 0.75072070
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ


                                   Domain Analysis: Age_range
                                                              Std Error
Age_range    Variable    Level                     Mean         of Mean       95% CL for Mean
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
16-18        Dist        Distraction           0.386874        0.036137    0.30813715 0.46561048
                         No Distraction        0.613126        0.036137    0.53438952 0.69186285
35-55        Dist        Distraction           0.239815        0.014635    0.20792850 0.27170107
                         No Distraction        0.760185        0.014635    0.72829893 0.79207150
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
```

PROC SURVEYFREQ

The SURVEYFREQ procedure can be used for multiple statistical computations. The most basic use is to determine the frequency of a variable. Even though this is supposed to represent a count, there will be inherent variability in this estimate because of the stratification and clustering of the dataset. The SURVEYFREQ will account for these elements. An example is given below. Another feature of SURVEYFREQ is its ability to compute relative risks and odds ratios, as was done in the example. This allows you to compare the frequency of a variable between two populations and/or time periods.

```
PROC surveyfreq data = age_Distraction;

      table Age_Range*Dist / OR CLWT NOPERCENT; *--- OR option produces Odds
                                                 Ratio and Relative Risks ---;

            strata PSUSTRAT;  *--- Stratification Variable ---;
            cluster psu;      *--- Clustering Variable ---;
            weight CASEWGT;   *--- Case weight Variable ---;
      run;
```

The weighted frequency of each variable is given in the output below. Furthermore, the corresponding 95% confidence limits were computed because “CLWT” was included in the table statement. The SURVEYFREQ procedure also computed the odds ratio (OR) comparing the ratio of distracted to non-distracted crashes for teen and adults as well as the relative risk (RR) of a teen driver crash involving a distracted driver as compared to an adult. The equations given below describe how these were computed.

$$RR = \frac{\left(\frac{Distracted\ Teen\ Crashes}{All\ Teen\ Crashes}\right)}{\left(\frac{Distracted\ Adult\ Crashes}{All\ Adult\ Crashes}\right)} = \frac{\left(\frac{204{,}198}{527{,}815}\right)}{\left(\frac{377{,}844}{1{,}575{,}566}\right)} = 1.6132$$

$$OR = \frac{\left(\frac{Distracted\ Teen\ Crashes}{Not\ DistractedTeen\ Crashes}\right)}{\left(\frac{Distracted\ Adult\ Crashes}{Not\ Distracted\ Adult\ Crashes}\right)} = \frac{\left(\frac{204{,}198}{323{,}617}\right)}{\left(\frac{377{,}844}{1{,}197{,}722}\right)} = 2.0002$$

SURVEYFREQ Output

Data Summary

Number of Strata	12
Number of Clusters	24
Number of Observations	19561
Number of Observations Used	15525
Number of Obs with Nonpositive Weights	4036
Sum of Weights	5931123.03

Table of Age_range by Dist

Age_range	Dist	Frequency	Weighted Frequency	Std Dev of Wgt Freq	95% Confidence Limits for Wgt Freq	
16-18	Distraction	557	204198	41843	113029	295367
	No Distraction	821	323617	27604	263474	383761
	Total	1378	527815	65074	386030	669600
35-55	Distraction	1086	377844	34696	302248	453440
	No Distraction	3219	1197722	92430	996335	1399109
	Total	4305	1575566	115507	1323898	1827233
Total	Distraction	1643	582042	64856	440733	723350
	No Distraction	4040	1521339	118597	1262939	1779739
	Total	5683	2103381	174008	1724250	2482512

Frequency Missing = 9842

Odds Ratio and Relative Risks (Row1/Row2)

	Estimate	95% Confidence Limits	
Odds Ratio	2.0002	1.3462	2.9717
Column 1 Relative Risk	1.6132	1.2464	2.0880
Column 2 Relative Risk	0.8065	0.7008	0.9282

Sample Size = 5683

The stratification and clustering variables vary by dataset and they must be identified by consulting the user's manual for that data source. Furthermore, there are many other SURVEY procedures in SAS that can also account for these survey design variables. A list of the SURVEY procedures included in SAS and their basic functions is provided in the SAS help menu are given below. Further help on how to request various statistical computations and outputs are also given in the SAS help menu.

PROC SURVEYFREQ

- estimates of population means and totals
- estimates of population proportions
- standard errors
- confidence limits
- hypothesis tests (t tests)
- domain analysis
- ratio estimates

PROC SURVEYLOGISTIC

- cumulative logit regression model fitting
- logit, complementary log-log and probit link functions
- generalized logit regression model fitting
- estimates of regression coefficients
- estimates of covariance matrices
- hypothesis tests
- model diagnostics
- estimates of odds ratios
- confidence limits
- estimable functions
- estimates and standard errors for contrasts
- domain analysis

PROC SURVEYMEANS

- estimates of population means and totals
- estimates of population proportions
- standard errors
- confidence limits
- hypothesis tests (t tests)
- domain analysis
- ratio estimates

PROC SURVEYPHREG

- regression analysis based on the Cox proportional hazards model
- hazard ratio estimates
- predicted values and their standard errors
- martingale, Schoenfeld, score, and deviance residuals
- significance tests
- confidence limits
- estimable functions

- domain analysis

PROC SURVEYREG

- linear regression model fitting
- estimates of regression coefficients
- estimates of covariance matrices
- significance tests
- confidence limits
- estimable functions
- estimates and standard errors for contrasts
- domain analysis

PROC SURVEYSELECT

- simple random sampling
- unrestricted random sampling (with replacement)
- systematic sampling
- sequential sampling
- selection probability proportional to size (PPS) with and without replacement
- PPS systematic sampling
- PPS for two units per stratum
- sequential PPS with minimum replacement

Poisson's Regression Analysis Code

```
Data V_agedist;
Set  Viol_Data;

      if 16 <= Age <= 18 then Age_range = '16-18';
      if 35 <= Age <= 55 then Age_range = '35-55';

*--- Compute the frequency of an event by year ----;
      Proc freq data = V_agedist;
      ods output CrossTabFreqs = Viol_Dist;     *--- Outputs frequency in
                                                table "Viol_Dist" ---;
      table Age_range *EV_Year; *--- Computes frequency by age and year ---;
      run;



*--- Merge frequency data with offset data, e.g. population counts ----;

Data Dist_All;;
merge  Viol_Dist  populations;
by caseyear Age_range;

      *--- Define comparison groups ----;
            if caseyear in (1997 1998 1999 ) then GDL = 1;
            if caseyear in (2005 2006 2007 2008) then GDL = 0;

      *---Take natural log of offset data to include in log-linear model----;
      ln = log(Census);

run;


*--- Poisson's Regression Annalysis ----;

    proc genmod data= Dist_All;
      class Age_range GDL; *--- Define model varibles ----;

      model Frequency = GDL Age_range GDL* Age_range
            / dist = NB       /*--- Negative Binomial Distribution ---*/

      link = log  dscale /*--- log linear model ---*/

      offset = ln;/**/  /*--- Offset included as log (population) ---*/
      run;
```