Transportation Research Part A 44 (2010) 182–193

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Evaluating the impact of legislation prohibiting hand-held cell phone use while driving

Alexander G. Nikolaev [a], Matthew J. Robbins [b], Sheldon H. Jacobson [c,*]

[a] Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, IL, United States
[b] Department of Industrial and Enterprise Systems Engineering, University of Illinois, Urbana, IL, United States
[c] Department of Computer Science, University of Illinois, Urbana, IL, United States

ARTICLE INFO

Article history:
Received 9 April 2009
Received in revised form 21 December 2009
Accepted 16 January 2010

Keywords:
Cell phone
Driving safety
Legislation
Automobile accident

ABSTRACT

As of November 2008, the number of cell phone subscribers in the US exceeded 267 million, nearly three times more than the 97 million subscribers in June 2000. This rapid growth in cell phone use has led to concerns regarding their impact on driver performance and road safety. Numerous legislative efforts are under way to restrict hand-held cell phone use while driving. Since 1999, every state has considered such legislation, but few have passed primary enforcement laws. As of 2008, six states, the District of Columbia (DC), and the Virgin Islands have laws banning the use of hand-held cell phones while driving. A review of the literature suggests that in laboratory settings, hand-held cell phone use impairs driver performance by increasing tension, delaying reaction time, and decreasing awareness. However, there exists insufficient evidence to prove that hand-held cell phone use increases automobile-accident-risk. In contrast to other research in this area that uses questionnaires, tests, and simulators, this study analyzes the impact of hand-held cell phone use on driving safety based on historical automobile-accident-risk-related data and statistics, which would be of interest to transportation policy-makers. To this end, a pre-law and post-law comparison of automobile accident rate measures provides one way to assess the effect of hand-held cell phone bans on driving safety; this paper provides such an analysis using public domain data sources. A discussion of what additional data are required to build convincing arguments in support of or against legislation is also provided.

1. Introduction

As of 2008, the Cellular Telecommunications and Internet Association (CTIA) reported that the number of cell phone subscribers in the US exceeded 267 million. The latest data available from the National Highway Traffic Safety Administration (NHTSA) estimated that in 2007, about 11% of the population used a phone while driving at some point during the day, as reported in *USA Today* (O'Donnell, 2009). Earlier studies revealed that approximately one-half of interviewed drivers reported using cell phones while driving, either to make outgoing calls or take incoming calls, spending an average of 4.5 min per call (Royal, 2003). Hand-held cell phones are believed to be an important factor in driver distraction (Williams, 2007). Driver distraction is thought to be the cause of nearly 80% of automobile accidents and 65% of near-accidents (Klauer et al., 2006), resulting in approximately 2600 deaths, 330,000 moderate to critical injuries, and 1.5 million instances of property damage annually in the US (Cohen and Graham, 2003). Nonetheless, car cell phones have been marketed for nearly half a century and continue to be viewed by many as a high-profile product, as evidenced by a recent article in *New York Times*

* Corresponding author.
E-mail address: shj@illinois.edu (S.H. Jacobson).

0965-8564/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tra.2010.01.006

(Richtel, 2009). Indeed, these facts are drawing a significant amount of public attention to the issue of hand-held cell phone use while driving.

Hand-held cell phone use while driving imposes no less than three tasks upon drivers: locating/glancing at the phone, which draws the eyes away from the road; reaching for the phone and dialing, which impairs control of the vehicle; and conversing via the phone, which distracts attention from driving (Klauer et al., 2006). Dialing a hand-held cell phone is a particularly dangerous task that forces a driver to take their eyes off the road, and thereby, increases the risk of accidents and near-accidents. The CTIA safe driving tips include never dialing a telephone or taking notes while driving (CTIA, 2008a). Cell phone use while driving has been considered and studied as a primary factor in automobile accidents, due to the high frequency of this activity (NHTSA, 1997).

Numerous investigations have been undertaken to determine whether hand-held cell phone use impairs driver performance. Such efforts are typically based on simulators, tests, questionnaires, telephone surveys, and observations. Redelemeier and Tibshirani (1997) associate hand-held cell phone use with automobile accidents by analyzing questionnaire responses of 699 drivers as well as phone and police records. They suggest that automobile-accident-risk is equivalent to impairment resulting from legal intoxication. Caird et al. (2008) and Horrey and Wickens (2006) show that the costs associated with cell phone use while driving are seen in reaction time tasks, with smaller costs in performance on lane keeping and tracking tasks. Strayer and Drews (2004) report that hand-held cell phone use while driving increases braking times by 18%, increases following distances by 12%, and increases the time for speed resumption after braking by 17%. The NHTSA used a driver simulator to investigate the effects of hand-held cell phone use while performing four tasks: car following, lead-vehicle braking, lead-vehicle cut in, and merging. They observed that hand-held cell phone use while driving impairs driver performance, increases the response to lead-vehicle speed changes during car following, and degrades automobile control (Ranney, 2005).

The growing use of cell phones and the associated research on how they impact driver performance have led many, including some state legislators, to question their safety while driving. Royal (2003) claims that 71% of drivers support restrictions on hand-held cell phones and 57% approve a ban on hand-held cell phone use while driving, although most drivers that do use cell phones oppose such outright bans or traffic fines on hands-free cell phones. Acknowledging a potential negative impact of hand-held cell phone use while driving, a number of legislative initiatives have passed that ban hand-held cell phone use while driving. In fact, since 1999, every state has considered such legislation (Sundeen, 2004). In 2001, New York became the first state to enact such a law. Since that time, similar bans have taken effect in New Jersey, DC, Connecticut, Utah, California, Washington, and the Virgin Islands, with all primary enforcement laws (except Utah where the law is primary only in regards to text messaging), which allows law enforcement officers to ticket drivers for using a hand-held cell phone while driving without any other traffic violation (Governors Highway Safety Association, 2008). A number of states (e.g., Illinois) restrict hand-held cell phone use by requiring sound to travel unimpaired to at least one ear or to have at least one hand on the steering wheel at all times (Sundeen, 2001). In addition to state statutes, local ordinances have been passed that prohibit hand-held cell phone use while driving in certain counties, cities, towns, and municipalities. For example, Chicago, Illinois, implemented such a policy in 2005. There are a total of 28 jurisdictions that enforced such local ordinances in Florida, Illinois, Massachusetts, Michigan, New Jersey, New Mexico, New York, Ohio, Pennsylvania, and Utah (Cellular News, 2008). However, no state or local ordinance completely bans all types of cell phones (hand-held and hands-free) while driving, though many prohibit cell phone use by certain segments of the population (Glassbrenner and Ye, 2007). For example, California enforces an all-type cell phone ban for school bus drivers and drivers under 18 years of age (AAA Auto Insurance, 2008).

While proponents believe that laws banning hand-held cell phone use while driving may reduce driver distraction and improve driver performance, opponents of such laws believe that it is premature to act. Although research suggests that multi-tasking impairs driver performance, there is still insufficient evidence to definitively prove that hand-held cell phone use increases automobile-accident-risk (McCartt et al., 2006; Williams, 2007; Olson, 2003). Note that in this domain, definitive proofs are practically impossible to obtain, given the inability of researchers to conduct controlled experiments where the dependent variables are accidents, property damage, personal injuries and even death. A study on distracted driving, released by the NHTSA and the Virginia Tech Transportation Institute (Dingus et al., 2006; Klauer et al., 2006), suggests that drivers talking or listening to a wireless device are no more likely to be involved in an accident or near-accident, than those not involved in such activities. Of course, the safety and highway travel benefits provided by cell phones, especially for public health and safety considerations, cannot be overlooked (Lissy et al., 2000). For example, cell phones can reduce emergency response time to automobile accidents (Savage et al., 2000). Moreover, given that legislation narrowly aimed toward cell phone use does not adequately address the larger issue of driver distraction, the CTIA believes that education is a more effective approach to enhance drivers' awareness and responsibility (CTIA, 2008b). A number of safety and elected officials agree with this sentiment, including the Chairman of the Governors Highway Safety Administration (CTIA, 2008b). To prove this point, in 2008, CTIA along with Sprint Nextel, Cingular Wireless, Dobson Cellular Systems, and other wireless companies, developed programs and sponsored public service announcement campaigns designed to educate drivers on distraction while operating vehicles.

In addition to education, the cell phone industry has focused on enhancing driving safety beyond the issue of hands-free operation, by eliminating in-hand manipulation and reducing distractions while driving (Goodman et al., 1997). Recent research and technological advances in this area are providing innovative solutions to the problem of distracted drivers, such as hands-free car kits and the "Polite Phone" prototype, using ground-breaking Bluetooth technology to provide a voice-command interface between a car and a cell phone and enable hands-free voice dialing, answering, and hanging up (Auto News, 2006; Funponsel Network, 2005). However, early reports failed to observe a significant risk reduction due to the use of this new technology (Strayer et al., 2003; McEvoy et al., 2005).

An important question to ask is: are bans on hand-held cell phone use while driving effective for reducing automobile-accident-risk, and do such laws make the roads safer? Although a significant amount of research has investigated the effect of hand-held cell phone use on automobile-accident-risk, there are no definitive conclusions on the issue. This paper focuses specifically on traffic safety both before and after hand-held cell phone bans, to explore whether such laws have any meaningful effect. Note that the issue of compliance is very important for such a study. In the paper, it is assumed, just as lawmakers assume, that the bans do make many drivers refrain from using hand-held cell phones while driving. The main contribution of this paper is to provide statistical measures in support of or against laws banning hand-held cell phone use while driving, based on their historical (statistical) impact on road safety, and to suggest what additional data are necessary to establish such connections.

The paper is organized as follows: Section 2 describes the available data and the statistical methods that can be used to conduct comparative studies of automobile accident rates in selected territorial units between pre-law and post-law time periods. Section 3 presents the observed results on the effects of law enforcement on improving driving safety. Section 4 summarizes the findings, discusses the limitations of the presented analysis of the effects of law enforcement on improving driving safety and points out possible directions for further research on this issue.

2. Methods

This section describes the data and the tools that can be used to compare automobile accident rates in selected territorial units for the time periods before and after hand-held cell phone ban laws were enacted in these units.

There is a dearth of systematically collected data on automobile accident rates in the United States that can be used to study the consequences of hand-held cell phone ban laws. Most territorial units have passed such laws just recently, and hence, can not be used as reliable testbeds for drawing any significant, long-lasting conclusions. In other cases, the ban laws have been passed individually by only a limited number of minor territorial units (e.g., isolated single counties), which makes it difficult to put the observed corresponding accident rate changes in a meaningful perspective. This paper looks to conduct a statistically significant, comprehensive analysis of pre-law and post-law periods, and focuses on the data for New York State, where a state-wide ban on hand-held cell phone use while driving began in November of 2001 (first in the US) and has been in effect for over 8 years. For the aforementioned reasons, New York data represent the only reliable source for evaluating the effect of hand-held cell phone ban laws in the United States.

Due to a change in the definition of property damage automobile accidents in New York State regulations in 1997 and again in 2003, the number of property damage automobile accidents, and hence, the total number of automobile accidents can not be used as a measure for evaluating the effectiveness of the ban. Therefore, for all 62 counties in New York State, the measures of traffic safety adopted in this study are the number of fatal automobile accidents per 100,000 licensed drivers per year and the number of personal injury accidents per 1000 licensed drivers per year. To allow for a proper comparison between time periods, 1997–2001 is treated as the pre-law time period and 2002–2007 is treated as the post-law time period. Note that these two accident rate measures are positively correlated, yet differ by the severity of the tallied accidents' consequences. Note also that some counties passed local ban laws prior to the enactment of the state-wide law. However, this consideration makes the results for any such county where the accident rates are found to have dropped, even stronger.

The main portion of the analysis is conducted by testing the hypothesis that the New York state-wide hand-held cell phone ban had no impact on the described measures. A one-tailed t-test is applied to determine whether the expected values for these measures show a statistically significant decrease after the law was enacted. First, to ensure that the data used are normally distributed, the Shapiro–Wilk test is conducted. Second, in order to determine a proper statistical test to be applied, the variances of the compared populations (the data collected over the two time periods) must be the same for each of the three measures. To assess this, a two-sided F-test is used. Third, for those localities when the null hypothesis of equal variances is not rejected at a 5% significance level, a one-sided t-test for samples with equal variances is used to determine whether the measures described above have the same means in the two time periods versus having larger means before hand-held cell phone ban laws were enacted. On the other hand, for those localities when the null hypothesis of equal variances is rejected at a 5% significance level, a one-sided t-test for samples with unequal variances is used.

3. Results

This section reports the results of the comparisons of two automobile accident measures in all New York State counties for the time periods before and after hand-held cell phone ban laws were enacted. The automobile accident rates data as well as the number of licensed drivers by county are all published by the New York State Department of Motor Vehicles (2008a–c).

The relevant data for each individual county of New York State are summarized in Tables 1 and 2. In particular, the two measures of interest, fatal accidents per 100,000 licensed drivers and personal injury accidents per 1000 licensed drivers, are reported for years 1997 through 2007. The counties are arranged in decreasing order by licensed driver density, computed as the number of licensed drivers per square mile (averaged over the 11 years comprising the pre-law and post-law periods). The last columns in Tables 1 and 2 give the p-values for the hypothesis test of equal variances in the pre-law and post-law accident rate measures, for each county.

Table 1
Fatal accidents per 100,000 licensed drivers for New York counties.

Index	County	Driver density	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	*p*-value
1	New York	28,659	13.812	9.879	10.769	10.96	8.371	7.426	9.133	6.757	9.392	9. 722	8.054	0.1434
2	Kings	11,450	17.044	14.551	14.265	12.777	13.431	11.437	10.116	10.421	12. 093	10.632	11.218	0.0549
3	Bronx	9617	18.982	12.816	15.258	12.236	13.457	14.27	10.839	12.651	10. 366	10.505	6.646	0.4385
4	Queens	9363	12.616	11.373	11.778	9.698	9.954	10.506	9.652	7.574	8. 811	8.13	6.588	0.4052
5	Richmond	4807	5.484	8.514	5.708	8.865	9.745	7.129	7.459	7.83	7.208	7. 634	5.781	0.0274
6	Nassau	3410	11.696	10.55	12.811	9.639	9.442	11.226	10.377	11.082	10. 128	8.56	9.025	0.2781
7	Westchester	1468	8.782	8.442	8.24	8.844	8.439	11.242	7.874	9.074	6. 746	8.341	5.566	0.0008
8	Rockland	1175	13.201	13.135	11.055	8.868	9.731	12.218	8.45	13.801	10. 664	13.653	8.176	0.3339
9	Suffolk	1149	14.84	16.311	15.257	14.706	15.656	14.278	14.253	14.578	13. 909	13.391	14.358	0.1813
10	Monroe	769	8.45	7.262	9.906	9.536	10.857	9.88	7.149	11.703	9.294	9. 743	7.47	0.3621
11	Erie	613	12.119	11.889	11.935	9.882	11.859	9.401	9.993	10.093	8.036	8. 69	8.096	0.4706
12	Schenectady	546	5.421	5.481	6.444	11.801	9.876	6.251	4.373	10.511	6. 17	9.493	5.932	0.3303
13	Onondaga	405	12.584	12.008	11.049	6.396	9.505	11.076	10.844	10.619	10. 099	9.328	10.399	0.0048
14	Albany	373	11.29	10.207	7.483	12.045	10.322	9.181	0.998	8.52	6.57	11. 899	10.237	0.0751
15	Putnam	323	18.59	17.025	21.034	13.66	13.428	15.951	15.331	10.294	14. 379	17.129	18.185	0.3556
16	Niagara	301	11.564	13.569	11.654	8.308	15.884	15.932	11.273	10.752	8. 949	13.819	9.894	0.4333
17	Orange	286	18.452	14.545	19.884	13.448	15.71	18.226	19.146	15.817	19. 174	17.771	15.028	0.1807
18	Dutchess	251	16.589	14.373	15.271	14.862	19.581	7.389	15.262	18. 622	14.898	8.578	10.279	0.087
19	Broome	201	9.92	15.688	15.067	13.432	9.132	9.168	8.942	9.749	11.27	13. 225	9.596	0.1108
20	Saratoga	190	7.745	13.278	15.861	10.744	11.841	9.618	9.979	11.167	12. 424	14.017	8.344	0.2127
21	Rensselaer	165	9.606	17.386	10.632	14.251	14.102	16.731	9.105	12. 764	11.927	10.776	10.557	0.3562
22	Chemung	153	16.228	13.036	17.929	9.6	9.564	11.291	17.336	9.6	12.99	17. 685	7.913	0.4691
23	Oneida	132	14.413	10.121	19.673	11.254	12.427	16.835	12.281	14.254	8. 809	16.654	12.148	0.3281
24	Tompkins	131	19.402	10.591	8.752	10.268	11.74	13.228	14.167	20.79	14. 654	11.385	11.145	0.3492
25	Ontario	116	15.485	23.871	20.963	19.145	24.269	17.293	20.856	23. 469	22.321	15.449	21.424	0.3646
26	Ulster	116	9.759	16.22	16.116	16.574	20.948	15.268	17.126	18.626	18. 765	20.773	24.058	0.2807
27	Wayne	114	23.856	20.872	13.403	16.101	30.527	20.384	17.144	21.542	18. 943	15.702	12.678	0.0719
28	Seneca	93	25.735	25.775	8.572	25.261	16.657	41.418	24.323	16.392	29. 01	12.285	48.469	0.1306
29	Oswego	90	23.795	27.533	28.665	28.248	21.003	26.824	21.769	19.66	24. 493	18.398	18.146	0.4712
30	Genesee	89	32.214	25.378	30.064	25.054	43.008	15.876	37.913	11.242	9. 138	31.356	30.908	0.1737
31	Montgomery	89	11.25	17.038	2.838	16.813	22.327	13.972	24.858	13. 921	22.521	16.489	16.221	0.163
32	Chautauqua	89	29.249	19.938	10.547	18.729	13.475	12.544	13.281	16. 615	17.898	18.854	14.482	0.0221
33	Fulton	80	7.779	12.933	7.746	5.06	7.557	17.534	27.195	12.424	35. 086	14.659	19.232	0.0276
34	Cayuga	79	29.745	14.958	18.618	18.316	9.082	9.074	14.294	27.058	9. 116	16.098	12.356	0.391
35	Orleans	76	23.814	34.124	23.918	6.772	30.322	23.742	39.953	16.782	13. 614	19.906	19.693	0.3916
36	Madison	76	12.466	35.295	20.7	18.341	24.266	14.103	21.735	29.719	11. 977	23.576	11.602	0.375
37	Columbia	74	28.978	31.133	17.704	23.875	6.41	25.275	18.572	35.276	31. 372	10.284	8.081	0.4286
38	Tioga	73	5.414	10.834	8.144	10.709	26.491	13.276	20.633	10.387	10. 493	15.589	22.979	0.1767
39	Livingston	71	16.16	18.422	9.157	17.976	17.862	40.178	15.305	15. 416	20.088	19.702	10.798	0.0402
40	Cortland	65	25.135	22.104	25.402	9.341	18.537	18.513	3.028	12.267	27. 967	18.304	18.034	0.346
41	Warren	57	23.675	6.415	16.971	14.454	14.29	10.013	19.529	5.847	27. 319	15.284	15.036	0.3687
42	Greene	57	51.821	25.845	19.949	19.524	22.018	32.378	21.189	13.202	23. 843	20.749	17.84	0.0651
43	Sullivan	56	19.333	33.009	23.165	20.783	18.526	21.745	33.329	24. 532	22.989	33.414	13.855	0.3321
44	Jefferson	55	11.695	16.203	16.261	18.947	24.553	21.532	11.223	15. 525	22.835	18.296	11.036	0.4609
45	Clinton	52	24.982	11.592	28.862	28.333	24.127	14.655	10.713	14.25	12. 554	19.408	20.811	0.1183
46	Washington	52	14.629	26.801	19.408	26.077	18.748	25.441	18.117	13. 481	13.561	15.448	15.156	0.3789
47	Steuben	52	27.115	12.858	22.784	18.166	16.583	26.395	17.69	11.036	19. 586	20.645	21.654	0.4139
48	Wyoming	50	37.657	34.172	27.245	37.133	30.181	23.606	26.445	30.03	23. 625	19.939	26.374	0.2812
49	Yates	50	24.316	0	48.603	29.826	17.724	23.687	17.431	17.592	5.923	17. 57	23.115	0.023
50	Cattaraugus	45	20.932	17.466	24.437	22.344	22.165	8.58	16.817	18. 731	20.777	20.549	20.375	0.1336
51	Otsego	44	21.451	23.776	21.272	20.959	25.312	15.963	13.452	15.754	13. 589	20.183	33.131	0.0101
52	Chenango	42	29.848	13.604	21.711	24.057	23.897	18.578	26.036	28.904	5. 296	10.343	22.891	0.2016
53	Schuyler	42	15.064	7.431	29.595	7.266	7.219	7.224	14.169	0	21.825	7. 11	0	0.3781
54	Schoharie	38	23.144	35.815	26.711	8.739	25.843	8.502	20.917	16.649	20. 896	20.39	8.044	0.165
55	Herkimer	32	13.289	13.335	11.119	21.955	15.302	13.147	17.359	24.09	15. 55	10.852	0	0.1143
56	Allegany	32	18.571	18.622	40.497	12.274	27.47	36.623	20.911	30.246	21. 451	36.325	17.923	0.2736
57	Saint Lawrence	28	19.003	21.812	31.354	28.322	21.473	22.919	17.203	13.34	14. 877	14.563	24.734	0.4164
58	Delaware	26	16.496	16.576	35.834	37.901	10.704	21.084	23.326	49. 643	21.208	21.018	31.205	0.4119
59	Franklin	21	21.306	6.103	21.373	27.089	20.805	20.62	11.572	23.238	20. 49	11.492	5.649	0.3884
60	Essex	16	18.691	18.623	14.841	32.639	28.627	24.773	27.644	27.773	28. 001	48.349	23.822	0.3678
61	Lewis	15	21.055	26.348	31.45	31.035	15.397	30.714	25.183	15.156	30. 713	55.041	29.516	0.115
62	Hamilton	3	0	63.264	20.877	41.212	40.984	41.152	20.321	0	20.678	20. 82	0	0.184

Tables 3 and 4 present the results of the *t*-tests for each individual county, reporting the test type, the standardized *t*-statistic values, and the *p*-values. A drop in the number of fatal accidents per 100,000 licensed drivers per year has been observed from the selected pre-law period to the post-law period in 46 counties. A drop in the number of personal injury

Table 2
Personal injury accidents per 1000 licensed drivers for New York counties.

Index	County	Driver density	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	p-value
1	New York	28,659	26.789	25.523	23.951	22.898	21.396	19.812	16.887	15.650	15. 110	15.197	14.202	0.4379
2	Kings	11,450	32.509	33.809	33.173	33.088	30.526	29.461	24.973	22.261	21. 002	20.094	19.150	0.0255
3	Bronx	9617	28.747	28.956	30.929	32.947	30.453	29.470	25.819	21.688	20. 270	20.424	20.792	0.0753
4	Queens	9363	22.410	23.517	23.830	23.721	22.451	22.038	18.333	16.159	15. 725	14.862	14.511	0.0089
5	Richmond	4807	16.188	16.269	14.491	14.055	14.351	13.749	12.586	11. 786	11.156	9.550	9.776	0.2190
6	Nassau	3410	17.573	17.688	17.374	17.744	16.781	17.307	16.137	15.608	14. 899	14.031	13.628	0.0153
7	Westchester	1468	13.949	14.037	13.586	13.696	13.168	13.161	12.175	11. 135	11.081	10.582	9.986	0.0185
8	Rockland	1175	15.222	14.393	14.723	15.568	14.548	14.515	13.745	13. 578	13.355	11.615	11.591	0.0539
9	Suffolk	1149	14.796	15.076	14.580	14.835	14.372	14.735	13.696	13. 564	12.728	12.673	12.568	0.0227
10	Monroe	769	12.766	12.176	12.266	13.108	12.038	12.673	11.410	11.403	11. 189	9.809	9.876	0.0574
11	Erie	613	12.646	12.220	12.516	13.057	11.882	12.746	12.123	12.083	11. 996	11.248	11.266	0.3205
12	Schenectady	546	11.185	10.249	10.725	11.084	10.648	11.912	10.696	9. 740	10.622	9.260	8.991	0.0299
13	Onondaga	405	14.313	14.734	14.653	14.171	12.794	13.202	12.985	11. 940	11.488	10.255	10.558	0.2077
14	Albany	373	17.139	16.057	15.922	16.433	14.533	14.935	16.230	14.048	14. 469	12.459	12.294	0.1992
15	Putnam	323	14.772	12.911	13.378	13.100	12.757	11.618	11.268	11.645	11. 360	11.147	11.028	0.0118
16	Niagara	301	12.399	11.075	12.243	12.104	11.074	11.018	11.166	10. 158	10.732	8.580	8.577	0.1356
17	Orange	286	15.727	15.783	16.235	16.415	15.378	16.238	15.077	14.929	14. 062	12.754	12.837	0.0195
18	Dutchess	251	15.139	14.086	14.839	14.119	13.250	13.055	13.077	12. 825	12.288	10.665	10.447	0.1829
19	Broome	201	12.201	11.367	12.096	13.106	11.415	11.397	11.020	10.362	9. 397	8.729	8.959	0.2019
20	Saratoga	190	10.659	9.644	9.806	9.542	8.789	8.579	8.881	8.356	8.287	7. 563	6.818	0.4166
21	Rensselaer	165	12.285	11.774	11.512	11.867	9.975	10.680	9.988	9.691	9. 881	8.405	8.454	0.4981
22	Chemung	153	10.370	11.358	11.425	11.039	10.010	10.307	8.778	9.680	9. 613	8.456	8.514	0.3709
23	Oneida	132	13.937	13.846	13.803	13.767	12.980	12.670	12.724	11.943	11. 634	9.937	9.463	0.0145
24	Tompkins	131	12.435	10.997	12.515	12.664	10.734	11.095	10.704	10. 219	9.948	9.108	9.601	0.2998
25	Ontario	116	12.726	10.700	11.097	11.719	10.220	11.028	10.806	9.609	9. 558	8.549	8.733	0.4704
26	Ulster	116	14.849	14.330	13.876	14.206	12.499	13.482	13.105	12.777	13. 015	11.099	11.183	0.3920
27	Wayne	114	10.124	10.287	9.531	9.471	8.489	8.284	8.329	8.114	6.980	6. 538	6.593	0.3630
28	Seneca	93	10.894	10.009	12.130	11.452	10.369	11.390	10.662	9.262	10. 402	8.845	9.209	0.3825
29	Oswego	90	12.707	12.174	11.860	12.747	12.089	12.118	11.549	9.899	9. 074	8.797	9.130	0.0142
30	Genesee	89	14.404	13.335	13.390	14.258	12.336	14.447	13.760	12.434	13. 638	9.922	12.032	0.1087
31	Montgomery	89	13.866	12.523	11.238	10.424	9.712	11.177	10.772	10. 190	9.769	9.179	9.652	0.0541
32	Chautauqua	89	11.887	14.276	11.170	11.352	10.542	11.248	11.238	10. 634	10.296	9.490	9.330	0.1293
33	Fulton	80	12.318	11.666	11.928	12.044	10.681	12.249	11.100	11.703	9. 799	7.989	8.558	0.0363
34	Cayuga	79	12.530	11.387	11.506	12.455	10.444	10.852	10.649	11.040	10. 009	9.677	8.949	0.4282
35	Orleans	76	10.104	9.896	8.405	8.871	8.356	9.124	8.424	7.821	7.964	6. 337	7.057	0.3764
36	Madison	76	11.926	10.215	10.184	11.249	9.322	11.182	10.077	9.688	9. 661	8.841	8.373	0.4580
37	Columbia	74	13.218	12.387	11.685	10.527	10.982	10.763	10.214	9.628	9. 809	8.289	8.626	0.3788
38	Tioga	73	9.582	8.613	9.528	9.290	7.338	8.178	7.763	8.180	7.713	6. 314	7.328	0.2642
39	Livingston	71	10.666	9.833	10.210	10.202	10.271	10.111	9.380	9.030	8. 861	7.246	8.444	0.0201
40	Cortland	65	14.327	12.378	13.082	11.956	11.678	13.082	13.262	11. 991	10.938	10.739	10.219	0.3707
41	Warren	57	15.432	14.583	14.574	14.000	13.004	13.397	12.538	12.746	12. 118	10.087	10.788	0.2642
42	Greene	57	12.552	10.740	10.943	10.934	10.046	11.467	12.396	10.878	11. 524	8.715	8.716	0.1671
43	Sullivan	56	15.640	13.903	13.899	13.452	12.838	13.989	13.788	13. 510	13.369	11.537	11.863	0.4854
44	Jefferson	55	12.776	11.607	12.122	11.018	10.977	10.723	9.540	11. 362	10.861	9.767	10.098	0.4204
45	Clinton	52	11.991	11.997	11.102	11.390	10.449	11.504	10.159	9.369	9. 272	8.981	8.758	0.2053
46	Washington	52	11.460	10.550	11.426	10.194	10.405	10.408	9.285	9.482	8. 973	7.923	8.206	0.2192
47	Steuben	52	10.347	9.258	10.552	11.193	9.577	10.030	9.662	9.229	8. 758	8.465	7.796	0.4719
48	Wyoming	50	10.441	10.627	11.102	10.465	9.624	10.386	9.884	9.776	8. 674	8.108	8.539	0.1632
49	Yates	50	8.085	6.983	6.622	6.920	7.267	8.290	6.798	6.157	5.864	6. 559	8.148	0.1323
50	Cattaraugus	45	11.617	10.759	10.630	11.138	9.633	11.240	9.552	9.570	9. 678	9.281	9.287	0.5109
51	Otsego	44	11.988	11.365	13.401	11.737	10.355	12.246	10.919	10.871	9. 671	9.105	9.873	0.4968
52	Chenango	42	11.125	10.067	11.398	11.040	10.515	10.191	9.816	9.354	7. 997	8.688	8.164	0.1686
53	Schuyler	42	9.641	9.066	10.136	10.682	9.241	9.824	9.423	9.742	8. 439	10.451	9.391	0.5134
54	Schoharie	38	10.692	10.028	9.927	10.880	11.457	10.925	10.542	9.823	9. 821	7.911	8.608	0.1360
55	Herkimer	32	10.410	8.890	9.696	10.165	8.569	10.364	9.200	9.373	8. 375	6.815	7.990	0.2076
56	Allegany	32	10.585	9.280	10.405	9.114	8.790	9.827	9.559	8.832	9.101	7. 749	9.171	0.3996
57	Saint Lawrence	28	10.180	9.325	9.447	10.007	9.703	9.545	9.117	8.671	7.641	7. 639	7.668	0.0623
58	Delaware	26	11.932	10.249	10.861	11.370	10.089	10.516	8.864	10.033	10. 100	8.066	8.503	0.3166
59	Franklin	21	11.414	11.320	11.786	10.625	9.957	10.516	9.489	9.498	8. 664	9.337	9.632	0.3307
60	Essex	16	13.196	11.733	12.911	11.750	11.272	11.148	10.159	11.838	10. 361	8.254	9.019	0.1951
61	Lewis	15	9.685	8.273	9.540	9.466	8.366	10.289	8.864	9.245	7.371	7. 205	6.789	0.1006
62	Hamilton	3	12.234	8.224	12.526	12.776	8.607	12.551	10.567	13.769	12. 614	8.745	6.160	0.3326

accidents per 1000 licensed drivers per year has been observed in all 62 counties. According to Table 3, which looks at the number of fatal automobile accidents per year per 100,000 licensed drivers, a total of 10 out of 62 counties have p-values lower than 0.05 in the t-tests, providing sufficient evidence for the rejection of the "no effect" hypotheses at the 5% level

Table 3
Post-law and pre-law comparison – fatal injury accidents per 100,000 licensed drivers.

Index	County	Driver density	Test type	*T*	*p*-value
1	New York	28,659	Pooled	2.4282	0.019
2	Kings	11,450	Pooled	4.6581	0.0006
3	Bronx	9617	Pooled	2.297	0.0236
4	Queens	9363	Pooled	3.1277	0.0061
5	Richmond	4807	Not pooled	0.5757	0.2895
6	Nassau	3410	Pooled	1.0108	0.1693
7	Westchester	1468	Not pooled	0.5062	0.3167
8	Rockland	1175	Pooled	0.0272	0.4894
9	Suffolk	1149	Pooled	3.7777	0.0022
10	Monroe	769	Pooled	−0.0043	0.5017
11	Erie	613	Pooled	4.4579	0.0008
12	Schenectady	546	Pooled	0.4335	0.3374
13	Onondaga	405	Not pooled	−0.0754	0.5284
14	Albany	373	Pooled	1.2737	0.1173
15	Putnam	323	Pooled	0.849	0.2089
16	Niagara	301	Pooled	0.2607	0.4001
17	Orange	286	Pooled	−0.8355	0.7875
18	Dutchess	251	Pooled	1.6785	0.0638
19	Broome	201	Pooled	1.6448	0.0672
20	Saratoga	190	Pooled	0.6341	0.2709
21	Rensselaer	165	Pooled	0.7025	0.2501
22	Chemung	153	Pooled	0.1973	0.424
23	Oneida	132	Pooled	0.0393	0.4848
24	Tompkins	131	Pooled	−0.8955	0.8031
25	Ontario	116	Pooled	0.302	0.3848
26	Ulster	116	Pooled	−1.5012	0.9162
27	Wayne	114	Pooled	1.0435	0.162
28	Seneca	93	Pooled	−1.1665	0.8633
29	Oswego	90	Pooled	2.071	0.0341
30	Genesee	89	Pooled	1.3517	0.1047
31	Montgomery	89	Pooled	−1.0848	0.8469
32	Chautauqua	89	Not pooled	0.822	0.2248
33	Fulton	80	Not pooled	−3.1774	0.9944
34	Cayuga	79	Pooled	0.812	0.2189
35	Orleans	76	Pooled	0.2531	0.4029
36	Madison	76	Pooled	0.7186	0.2453
37	Columbia	74	Pooled	0.0223	0.4914
38	Tioga	73	Pooled	−0.794	0.7762
39	Livingston	71	Not pooled	−0.8802	0.7992
40	Cortland	65	Pooled	0.8181	0.2172
41	Warren	57	Pooled	−0.0818	0.5317
42	Greene	57	Pooled	1.0117	0.1691
43	Sullivan	56	Pooled	−0.4882	0.6815
44	Jefferson	55	Pooled	0.2667	0.3979
45	Clinton	52	Pooled	2.4495	0.0184
46	Washington	52	Pooled	1.4584	0.0894
47	Steuben	52	Pooled	0.0001	0.5
48	Wyoming	50	Pooled	3.4703	0.0035
49	Yates	50	Not pooled	0.7844	0.2346
50	Cattaraugus	45	Pooled	1.6268	0.0691
51	Otsego	44	Not pooled	1.2213	0.1348
52	Chenango	42	Pooled	0.8245	0.2155
53	Schuyler	42	Pooled	0.9009	0.1955
54	Schoharie	38	Pooled	1.6895	0.0627
55	Herkimer	32	Pooled	0.3764	0.3577
56	Allegany	32	Pooled	−0.651	0.7343
57	Saint Lawrence	28	Pooled	2.1479	0.0301
58	Delaware	26	Pooled	−0.6149	0.7231
59	Franklin	21	Pooled	0.8606	0.2059
60	Essex	16	Pooled	−1.4389	0.908
61	Lewis	15	Pooled	−0.9157	0.8081
62	Hamilton	3	Pooled	1.352	0.1047

of significance. According to Table 4, which looks at the number of personal injury automobile accidents per year per 1000 licensed drivers, a total of 46 out of 62 counties have *p*-values lower than 0.05 in the *t*-tests. Fig. 1 presents the personal injury accident rate standardized *t*-statistic values for the hypothesis tests for all counties, respectively, plotted against licensed driver density.

Table 4
Post-law and pre-law comparison – personal injury accidents per 1000 licensed drivers.

Index	County	Driver density	Test type	*T*	*p*-value
1	New York	28,659	Pooled	6.4023	0.0001
2	Kings	11,450	Not pooled	5.4407	0.0002
3	Bronx	9617	Pooled	4.0087	0.0015
4	Queens	9363	Not pooled	5.2087	0.0012
5	Richmond	4807	Pooled	4.2763	0.001
6	Nassau	3410	Not pooled	3.6932	0.0052
7	Westchester	1468	Not pooled	4.7516	0.0015
8	Rockland	1175	Pooled	3.1667	0.0057
9	Suffolk	1149	Not pooled	3.862	0.0039
10	Monroe	769	Pooled	2.7131	0.0119
11	Erie	613	Pooled	1.7638	0.0558
12	Schenectady	546	Not pooled	1.1196	0.1459
13	Onondaga	405	Pooled	3.7802	0.0022
14	Albany	373	Pooled	2.4899	0.0172
15	Putnam	323	Not pooled	5.4204	0.0018
16	Niagara	301	Pooled	2.9254	0.0084
17	Orange	286	Not pooled	2.7064	0.0174
18	Dutchess	251	Pooled	3.6016	0.0029
19	Broome	201	Pooled	3.5655	0.003
20	Saratoga	190	Pooled	3.6897	0.0025
21	Rensselaer	165	Pooled	3.6164	0.0028
22	Chemung	153	Pooled	3.8226	0.002
23	Oneida	132	Not pooled	3.8372	0.0044
24	Tompkins	131	Pooled	3.5403	0.0032
25	Ontario	116	Pooled	2.5992	0.0144
26	Ulster	116	Pooled	2.5664	0.0152
27	Wayne	114	Pooled	4.375	0.0009
28	Seneca	93	Pooled	1.7797	0.0544
29	Oswego	90	Not pooled	3.6964	0.0052
30	Genesee	89	Pooled	1.0372	0.1633
31	Montgomery	89	Pooled	1.9045	0.0446
32	Chautauqua	89	Pooled	2.1273	0.0311
33	Fulton	80	Not pooled	1.817	0.0513
34	Cayuga	79	Pooled	2.9287	0.0084
35	Orleans	76	Pooled	2.4076	0.0197
36	Madison	76	Pooled	1.5606	0.0765
37	Columbia	74	Pooled	3.6246	0.0028
38	Tioga	73	Pooled	2.6183	0.0139
39	Livingston	71	Not pooled	3.3509	0.0075
40	Cortland	65	Pooled	1.3652	0.1027
41	Warren	57	Pooled	3.5244	0.0032
42	Greene	57	Pooled	0.5391	0.3015
43	Sullivan	56	Pooled	1.485	0.0858
44	Jefferson	55	Pooled	2.957	0.008
45	Clinton	52	Pooled	3.2393	0.0051
46	Washington	52	Pooled	3.7247	0.0024
47	Steuben	52	Pooled	2.4693	0.0178
48	Wyoming	50	Pooled	2.6474	0.0133
49	Yates	50	Pooled	0.4013	0.3488
50	Cattaraugus	45	Pooled	2.2114	0.0272
51	Otsego	44	Pooled	1.9531	0.0413
52	Chenango	42	Pooled	3.9199	0.0018
53	Schuyler	42	Pooled	0.5177	0.3086
54	Schoharie	38	Pooled	1.7181	0.06
55	Herkimer	32	Pooled	1.3353	0.1073
56	Allegany	32	Pooled	1.289	0.1148
57	Saint Lawrence	28	Pooled	3.3032	0.0046
58	Delaware	26	Pooled	2.8361	0.0098
59	Franklin	21	Pooled	3.7613	0.0022
60	Essex	16	Pooled	2.979	0.0077
61	Lewis	15	Pooled	1.1327	0.1433
62	Hamilton	3	Pooled	0.0879	0.4659

A condensed version of further results is given in Tables 5 and 6, where a summary of the t-test results is presented for three different cases of pooled groups of counties. In the first case, the measures of all the counties in New York are pooled in order to obtain a statewide result. In the second case, the measures of the counties are pooled according to geopolitical designation in order to examine results for New York City and upstate New York. In the third case, the measures of the counties

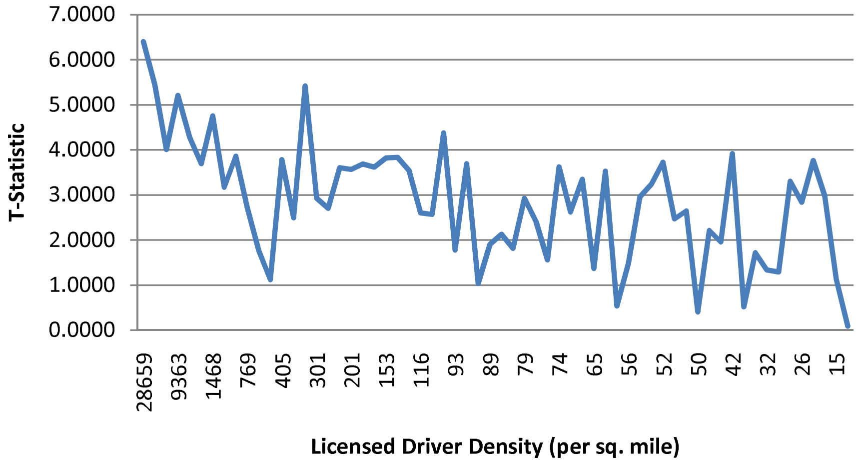

Fig. 1. Personal injury accident *t*-test statistic by county, pre-law to post-law.

Table 5
Post-law and pre-law comparison – fatal injury accidents per 100,000 licensed drivers.

Group	$\overline{X}_{post} - \overline{X}_{pre}$	S_p	$n_{pre},\ n_{post}$	T	p-value
NY state (1–62)	−1.399	8.516	310, 372	2.1362	0.0165
NY city (1–5)	−2.4942	*	25, 30	3.3787	0.0008
Upstate (6–62)	−1.3029	8.6093	285, 342	1.8869	0.0298
NY county (1)	−2.3441	1.5942	5, 6	2.4282	0.0190
Kings (2)	−3.4271	1.2150	5, 6	4.6581	0.0006
Bronx–Queens (3–4)	−3.1052	2.5026	10, 12	2.8979	0.0044
Richmond (5)	−0.4895	1.4041	5, 6	0.5757	0.2895
Nassau (6)	−0.7614	1.2439	5, 6	1.0108	0.1693
Westchester–Suffolk (7–9)	−0.5574	3.0764	15, 18	0.5182	0.3040
Monroe–Schenectady (10–12)	−1.0548	2.1419	15, 18	1.4086	0.0845
Onondaga–Dutchess (13–18)	−1.1261	3.9705	30, 36	1.1473	0.1278
Broome–Wayne (19–27)	−0.4038	4.6819	45, 54	0.4273	0.3351
Seneca–Hamilton (28–62)	−1.6651	9.2897	175, 210	1.7512	0.0404

Table 6
Post-law and pre-law comparison – personal injury accidents per 1000 licensed drivers.

Group	$\overline{X}_{post} - \overline{X}_{pre}$	S_p	$n_{pre},\ n_{post}$	T	p-value
NY state (1–62)	−1.8870	*	310, 372	6.1656	0.0000
NY city (1–5)	−6.9960	5.8108	25, 30	4.4459	0.0000
Upstate (6–62)	−1.4388	2.0508	285, 342	8.7473	0.0000
NY county (1)	−7.9685	2.0554	5, 6	6.4023	0.0001
Kings (2)	−9.7975	2.9739	5, 6	5.4407	0.0002
Bronx–Queens (3–4)	−6.7886	4.2875	10, 12	3.6979	0.0007
Richmond (5)	−3.6370	1.4046	5, 6	4.2763	0.0010
Nassau (6)	−2.1637	*	5, 6	3.6932	0.0052
Westchester–Suffolk (7–9)	−1.8542	*	15, 18	5.1424	0.0000
Monroe–Schenectady (10–12)	−0.8465	1.0439	15, 18	2.3196	0.0136
Onondaga–Dutchess (13–18)	−1.9896	1.7729	30, 36	4.5398	0.0000
Broome–Wayne (19–27)	−1.8302	1.6593	45, 54	5.4646	0.0000
Seneca–Hamilton (28–62)	−1.2382	1.6556	175, 210	7.3070	0.0000

are pooled according to licensed driver density values. In particular, a *k*-means clustering algorithm (Seber, 1984) is used to form 10 groups of counties with similar licensed driver density values. The algorithm selects group membership in order to minimize the total intra-group Euclidean distance between a county's density value and its group's mean density value. Each table reports the difference in its respective measure from the selected pre-law period to the post-law period, the pooled sample standard deviation (when appropriate), the number of data points in the samples, the values of the test statistic (T is distributed $t_{n_{pre}+n_{post}-2}$) and the p-values. For most of the pooled groups, the hypothesis of equal variances of accident rate measures between the pre-law and post-law periods was not rejected. Those groups that rejected the hypothesis of equal variances have a $*$ in the S_p column.

4. Discussion

As the number of drivers that use cell phones while driving grows, the interest in linking hand-held cell phone use while driving and road safety increases. As more technologies, including cameras, music, text messaging, and internet browsing become available from mobile devices, they may pose an even greater cause of driver distraction. As of 2009, more than 250 bills prohibiting or restricting cell phone use while driving are pending in 42 state legislatures, despite disagreement over the risks cell phones pose and the effectiveness of enforcement (O'Donnell, 2009).

This paper conducts a comparative analysis of two automobile accident rate measures in the counties of New York State for the periods before and after the state-wide hand-held cell phone ban law was enacted. Section 4.1 summarizes the findings, Section 4.2 discusses the limitations of the presented analysis of the effects of law enforcement on improving driving safety, and Section 4.3 points out the possible directions for further research on this subject.

4.1. Summary

The results presented in Section 3 indicate that after banning hand-held cell phone use while driving, 46 counties in New York experienced lower fatal automobile accident rates, 10 of which did so at a statistically significant level, and all 62 counties experienced lower personal injury automobile accident rates, 46 of which did so at a statistically significant level.

The analysis strongly suggests that the mean fatal accident rate measure decreased at a significant level for New York State (p-value of 0.0165, see Table 5), for New York City and upstate New York (p-values of 0.0008 and 0.0298, respectively, see Table 5), and for four of the 10 groups partitioned by similar licensed driver density. Three of these four groups contained high density New York City counties (New York County, Bronx, and Queens with p-values of 0.0190, 0.0006, and 0.0044, respectively, see Table 5). The fourth group contained the lowest density subset of upstate New York counties (Seneca–Hamilton, with a p-value of 0.0404, see Table 5).

The mean personal injury accident rate measure decreased at a significant level for all groups in each of the three cases examined (see Table 6). Moreover, it has been observed that, in general, the personal injury accident rate decrease is more substantive in counties with a high density of licensed drivers (see Fig. 1). Overall, the personal injury accident rate proved to be a more appropriate measure than the fatal accident rate for the analysis.

4.2. Limitations

There exist several issues that limit the statistical validity of the presented analysis and hamper one's ability to definitively establish the effect of laws banning hand-held cell phone use while driving on automobile accident rates using publicly available, historical data as the basis for analysis. First, one should take care not to project the results of this analysis based only on New York data to the national level, given that each state, county, city, and town has their own unique highway and roadway transportation network that, by their very design, must be considered.

Second, hand-held cell phone ban legislation may not be the only way to affect automobile accident rates. This observation makes it difficult to judge whether the changes in automobile accident rates in counties with hand-held cell phone bans are primarily attributed to the bans, or to some other factors, including but not limited to road construction, safety education, introduction of new automobile safety features, and/or changes in alcohol and illegal substance control policies. Considerations of such *confounding* factors should ideally be included in the analysis, but unfortunately, the relevant data are unavailable due to their absence in the public records as well as proprietary concerns of the companies that use such data for their business interests. Also, the impact of traffic safety improvement thrusts, such as the "Safe Streets NYC" program in New York City (Bloomberg and Sadik-Khan, 2007), should be taken into account.

Third, proper enforcement of hand-held cell phone ban laws, and hence, driver compliance is an important issue. McCartt and Geary (2003, 2004) reported that the hand-held cell phone user rate while driving in New York dropped from 2.3% (before the law was enacted) to 1.1% in the first few months immediately following the enactment of the law. However, this rate rebounded back up to 2.1% about a year later. Since the initial drop in hand-held cell phone use while driving was not sustained, it is possible that the reduction in automobile accident rates in New York may be due to other factors.

Fourth, data linking the number of cell phone subscribers to automobile accident rates suggest that increased cell phone use does not translate into increased automobile accident rates. In particular, there has been an exponential growth in the number of cell phone subscribers from the late-1980s, while automobile accident rates in the US during this same time period have remained at a fairly constant level (see Fig. 2). Driving statistics from the National Center for Statistics and Analysis of the NHTSA reveals that from 1994 to 2004, the number of cell phone subscribers increased 655%, with their average monthly minutes-of-use increasing 3900%, while annual automobile accident rates reported decreased by approximately 5% over the same time period (Information Please Database, 2007; NHTSA, 2008). These facts should not go unnoticed, even though it is likely that the changes in the transportation policy and the advances in safety in the automotive industry between 1988 and 2006 have influenced the accident rates.

As of February 2007, sixteen states had published data on the number of automobile accidents that cited hand-held cell phones or radios as a causal factor. These data indicate that hand-held cell phone use is reported as a factor in less than 1% of automobile accidents (Sundeen, 2007). Although such data are controversial and potentially unreliable, due to the challenge

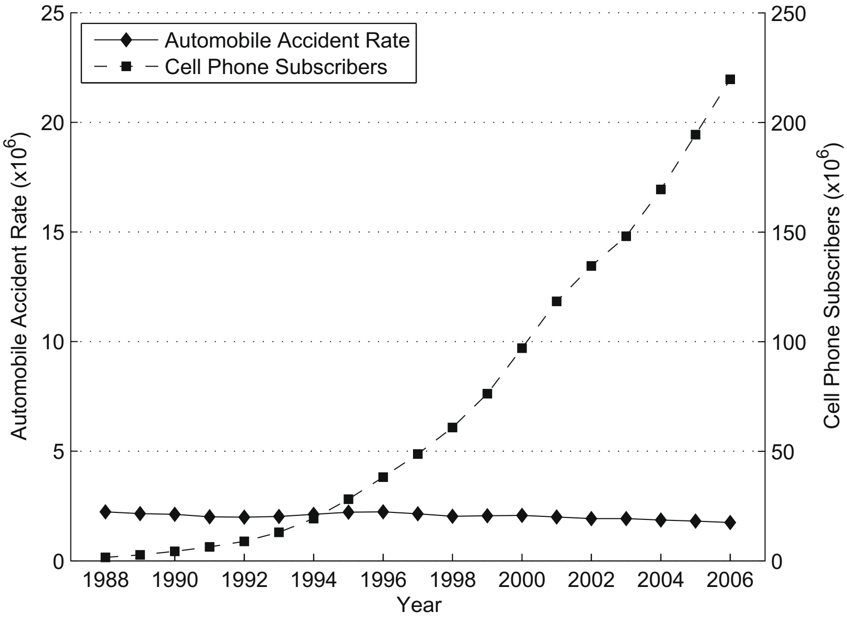

Fig. 2. Automobile accident rates and the number of cell phone subscribers in the US, 1988–2006.

in knowing the precise cause of accidents and how such information is reported, it does suggest that hand-held cell phone use may account for a negligible percentage of automobile accidents, which means that if such accidents could be completely eliminated by hand-held cell phone ban laws, there would be only a slight reduction in the total number of automobile accidents.

4.3. Future research directions

A large body of literature suggests that hand-held cell phone use while driving impairs driver performance (Ranney, 2005; Strayer et al., 2006; Sundeen, 2001; Redelemeier and Tibshirani, 1997). Drivers using hand-held cell phones have slower reaction times, longer following distances, and longer speed resume time compared to those drivers who do not use hand-held cell phones (Strayer and Drews, 2004). Although studies using driving simulators and test tracks indicate that hand-held cell phone use negatively impacts driver performance, the results drawn from experiments in such controlled environments cannot directly measure the impact of hand-held cell phone use on accident rates (Hedlund, 2006). Indeed, there is insufficient evidence to broadly assert that hand-held cell phone use results in higher accident rates or that hand-held cell phone bans decrease accident rates (Williams, 2007). Several organizations, including CTIA and AAA Auto Insurance, believe it is premature to ban hand-held cell phone use while driving. They argue that road safety can be improved more effectively through education and ease-of-use cell phone designs, rather than legislation.

Studies conducted in actual driving conditions, not only in laboratory environments, are needed to provide convincing evidence that hand-held cell phone use while driving impairs driver performance, and hence, increases automobile accident rates. However, staging a set of potentially dangerous situations on the road just to evaluate the driver's ability to avoid a collision is unthinkable, and hence, the statistical approach taken in this paper may be the only one where data from actual accidents can be used to answer questions regarding cell phone use while driving. Although at this point one should be cautious about drawing conclusions from the current analysis (for reasons described in Section 4.2), the approach taken in this paper looks very promising for providing useful information on the need for hand-held cell phone ban laws.

In order to conduct a more substantive and conclusive analysis, the data that would allow for blocking the confounding factors are required. Also, the property damage automobile accident rate should be considered as another, more appropriate measure of safety than fatal or personal injury accident rates. A measure that ideally would replace the density of licensed drivers in the analysis is the daily vehicle throughput per square mile of a county's land. Moreover, in order to investigate the effects of restricting hand-held cell phone use while driving, wider-coverage data related to cell phone usage and road safety are needed to support additional research on this important problem. Such data could include the fraction of drivers actually using hand-held cell phones while driving, the total amount of time that hand-held cell phones are used while driving, and the fraction of automobile accidents that are directly attributable to hand-held cell phone use. Note that the bonanza of the described data lies in the hands of insurance companies that must be interested in the correct evaluation of the impact of cell phone ban laws on driving safety, albeit only for the sake of gaining a competitive edge over their rivals. Moreover, national and state transportation policy law-makers would welcome a fair and unbiased analysis with such data, to put to rest the growing debate on this issue and allow for appropriate national and state legislation policies and decisions to be made.

Given more data, a logical step to take from the statistical point of view is to conduct a time series cross-sectional multivariate regression analysis and employ analysis of variance techniques to establish whether laws prohibiting hand-held cell phone use while driving have a significant effect on the driving environment. The authors do not intend to stop short of finding the truth and actively seek potential collaborations with interested parties.

Acknowledgements

The computational work was done in the Simulation and Optimization Laboratory housed within the Department of Computer Science at the University of Illinois. The views expressed in this paper are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government. The authors wish to thank the editor and two anonymous referees for their helpful comments and suggestions, which have significantly improved the manuscript. The authors would also like to thank Qianyi C. Zhao for her contributions during the initial stages of this research.

References

AAA Auto Insurance, Public Affairs, 2008. State Distracted Driving Laws Chart. %3chttp://www.aaapublicaffairs.com/Assets/Files/200891214340.DistractedDrivingLaws8.08.doc%3e (accessed 28.01.09).

Auto News, 2006. Hands-free Phone Kits Help Reduce Cell Phone Distraction. %3chttp://www.motortrend.com/auto_news/112_news060906_hands_free_cell_phone_use/index.html%3e (accessed 18.02.09).

Bloomberg M.R., Sadik-Khan, J., 2007. Safe Streets NYC. Traffic Safety Improvements in New York City. %3chttp://www.SafeNY.com%3e (accessed 18.10.09).

Caird, J.K., Willness, C.R., Steel, P., Scialfa, C., 2008. A meta-analysis of the effects of cell phones on driver performance. Accident Analysis and Prevention 40 (4), 1282–1293.

Cellular News, 2008. Countries that Ban Cell Phones while Driving. %3chttp://www.cellular-news.com/car_bans/%3e (accessed 28.01.09).

Cohen, J.T., Graham, J.D., 2003. A revised economic analysis of restrictions on the use of cell phones while driving. Risk Analysis 23 (1), 5–17.

CTIA, 2008a. Safe Driving Tips. %3chttp://www.ctia.org/consumer_info/safety/index.cfm/AID/10369%3e (accessed 28.01.09).

CTIA, 2008b. Safe Driving: CTIA Position. %3chttp://www.ctia.org/ad-vocacy/policy_topics/topic.cfm/TID/17%3e (accessed 28.01.09).

Dingus, T.A., Klauer, S.G., Neale, V.L., Petersen, A., Lee, S.E., Sudweeks, J., Perez, M.A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z.R., Jermeland, J., Knipling, R.R., 2006. The 100-car Naturalistic Driving Study, Phase II – Results of the 100-car Field Experiment. NHTSA, DOT HS 810 593. %3chttp://www.nhtsa.gov/portal/nhtsa_static_file_downloader.jsp?file=/sta-ticfiles/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2006/100CarMain.pdf%3e (accessed 28.01.09).

Funponsel Network, 2005. Motorola Develops 'Polite' Phone. %3chttp://www.funponsel.com/blog/news/motorola-develops-polite-phone.html%3e (accessed 18.02.09).

Glassbrenner, D., Ye, J.Q., 2007. Driver Cell Phone Use in 2006 – Overall Results. NHTSA, DOT HS 810 790 (July).

Goodman, M.J., Benel, D., Lerner, N., Wierwille, W., Tijerina, L., Bents, F., 1997. An Investigation of the Safety Implications of Wireless Communications in Vehicles. US Dept. of Transportation, NHTSA. %3chttp://www.nhtsa.dot.gov/people/injury/research/wireless/%3e (accessed 28.01.09).

Governors Highway Safety Association, 2008. Cell Phone Driving Laws. %3chttp://www.ghsa.org/html/stateinfo/laws/cellphone_laws.html#4%3e (accessed 28.01.09).

Hedlund, J.H., 2006. Countermeasures that Work: A Highway Safety Countermeasures Guide for State Highway Safety Offices. NHTSA, Washington, DC, DOT HS 809 980 (January). %3chttp://www.nhtsa.dot.gov/people/injury/airbags/Countermeasures/pages/0Introduction.htm%3e (accessed 28.01.09).

Horrey, W.J., Wickens, C.D., 2006. Examining the impact of cell phone conversations on driving using meta-analytic techniques. Journal of Experimental Psychology: Applied 12 (2), 67–78.

Information Please Database, 2007. Cell Phone Subscribers in the US, 1985–2005. %3chttp://www.infoplease.com/ipa/A0933563.html%3e (accessed 28.01.09).

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J.D., Ramsey, D.J., 2006. The Impact of Driver Inattention on Near-crash/Crash Risk: An Analysis Using the 100-car Naturalistic Driving Study Data. NHTSA, DOT HS 810 5940 (April). %3chttp://www.noys.org/Driver%20Inattention%20Report.pdf%3e (accessed 28.01.09).

Lissy, S.K., Cohen, J.T., Park, M.Y., Graham, J.D., 2000. Cellular Phone Use while Driving: Risks and Benefits. Harvard Center for Risk Analysis, Harvard School of Public Health. %3chttp://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/PDF/Harvard.PDF%3e (accessed 28.01.09).

McCartt, A.T., Geary, L.L., 2003. Drivers' use of handheld cell phones before and after New York State's cell phone law. Preventive Medicine 36, 629–635.

McCartt, A.T., Geary, L.L., 2004. Long term effects of New York State's law on drivers' handheld cell phone use. Injury Prevention 10, 11–15.

McCartt, A.T., Hellinga, L.A., Bratiman, K.A., 2006. Cell phones and driving: review of research. Traffic Injury Prevention 7 (2), 89–106.

McEvoy, S.P., Stevenson, M.R., McCartt, A.T., Woodward, M., Haworth, C., Palamara, P., Cercarelli, R., 2005. Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. British Medical Journal 331 (7514), 428–430.

NHTSA, 1997. Traffic Safety Facts 1996: Young Drivers. NHTSA, Washington, DC.

NHTSA, 2008. Table 2-17: Motor Vehicle Safety Data, National Transportation Statistics. %3chttp://www.bts.gov/publications/national_trans-portation_statistics/html/table_02_17.html%3e (accessed 28.01.09).

New York State Department of Motor Vehicles, 2008a. Ticket and Crash Data Reports by County in 2001–2006. %3chttp://www.nysgtsc.state.ny.us/hsdata.htm%3e (accessed 28.01.09).

New York State Department of Motor Vehicles, 2008b. The Number of All New York States Vehicle Registrations Considered Active in 1997–2006. %3chttp://www.nydmv.state.ny.us/stats-arc.htm%3e (accessed 28.01.09).

New York State Department of Motor Vehicles, 2008c. Driver Licenses and Vehicle Registrations by County in 1997–2006. %3chttp://www.nydmv.state.ny.us/stats-arc.htm%3e (accessed 28.01.09).

O'Donnell, J., 2009. Efforts to Limit Cellphone Use while Driving Grow. USA Today, March 30, 2009.

Olson, R.K., 2003. Cell Phone Bans for Drivers: Wise Legislation? International Risk Management Institute. %3chttp://www.irmi.com/Expert/Articles/2003/Olson05-a.aspx%3e (accessed 28.01.09).

Ranney, T.A., 2005. Examination of the Distraction Effects of Wireless Phone Interfaces Using the National Advanced Driving Simulator-Final Report on the Freeway Study. NHTSA, DOT HS 809 787.

Redelemeier, D.A., Tibshirani, R.J., 1997. Association between cellular-telephone calls and motor vehicle collisions. The New England Journal of Medicine 336, 453–458.

Richtel, M., 2009. Promoting the Car Phone, Despite Risks. New York Times, December 7, 2009.

Royal, D., 2003. Volume I: Findings National Survey of Distracted and Drowsy Driving Attitudes and Behavior: 2002. NHTSA, DOT HS 809 566.

Savage, M.A., Goehring, J.B., Mejeur, J., Reed, J.B., Sundeen, M., 2000. State Traffic Safety Legislative Summary 2000. Transportation Series (National Conference of State Legislatures). %3chttp://www.ncsl.org/programs/transportation/trafsafe00.htm%3e (accessed 28.01.09).

Seber, G.A.F., 1984. Multivariate Observations. John Wiley and Sons, Hoboken, NJ.

Strayer, D.L., Drews, F.A., 2004. Profiles in driver distraction: effects of cell phone conversations on younger and old drivers. Human Factors 46 (4), 640–649.
Strayer, D.L., Drews, F.A., Johnston, W.A., 2003. Cell phone-induced failures of visual attention during simulated driving. Journal of Experimental Psychology: Applied 1 (9), 23–32.
Strayer, D.L., Drews, F.A., Crouch, D.J., 2006. A comparison of the cell phone driver and the drunk driver. Human Factors 48 (2), 381–391.
Sundeen, M., 2001. Driving while calling – what's the legal limit? State Legislatures 27 (9), 24–26.
Sundeen, M., 2004. Cell Phones and Highway Safety: 2003 State Legislative Update. National Conference of State Legislatures. %3chttp://www.ncsl.org/print/transportation/cellphoneupdate12-03.pdf%3e (accessed 18.02.09).
Sundeen, M., 2007. Cell Phones and High Way Safety 2006 State Legislative Update. National Conference of State Legislatures. %3chttp://www.ncsl.org/print/transportation/2006cellphone.pdf%3e (accessed 28.01.09).
Williams, A.F., 2007. Contribution of the components of graduated licensing to crash reductions. Journal of Safety Research 38 (2), 177–184.