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Turn Signal Usage Rate Results: A Comprehensive Field Study of 12,000 Observed Turning Vehicles

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ABSTRACT

The turn signal is a vital safety feature that is not only required to be built in as standard equipment on all vehicles, but their use by the driver in everyday driving is required by law. Since not all drivers are diligent at properly actuating turn signals in every situation, the use of the turn signal is less than 100%. However, despite the fact that turn signals are a crash prevention feature, no known study relating to turn signal usage rates is available from the National Highway Traffic Safety Administration, nor from the Department of Transportation, nor from any University, nor from other private safety organizations.

This paper summarizes a first-ever published comprehensive study related to turn signal usage rates by everyday drivers and summarizes it in a simple, yet highly accurate naturalistic observation format with the following basic premise: A vehicle is observed to be turning in a situation that is deemed by the observer to require a turn signal: was the turn signal "on" or was it "off" in that observed vehicle? The summary of the cumulated data of turn signal usage is expressed in terms of a percentage usage rate. All turning drivers are unaware that their visible actions are data points in a study so the results are extremely accurate. Both turns as well as lane change usage rates are studied. Crash rates resulting from neglected turn signals are discussed, revealing that this neglect causes more crashes than distracted driving. The present turn signal system that relies solely on driver input can only be described as "defective". The paper also discusses how patented Electronic Intelligent Turn Signals with Turn Signal Assist would vastly improve usage rates and therefore significantly lower crash rates for no added vehicle cost.

INTRODUCTION

This paper summarizes an on-the-road investigation into usage rates of turn signals that we as drivers would typically encounter on our roadways. In a first of its kind study, observed rates of turn signal usage were gathered from a total of 12,000 vehicles using a simple observation method in a naturalistic setting on public roadways: When a vehicle is observed executing a turn or a lane change, that vehicle's coinciding turn signal on-or-off status is recorded.

The published SAE paper 2010-01-0744, entitled "Smart Turn Signal Technology - Advancing Crash Prevention and Combating Distracted Driving with Control Algorithm Enhancements" (1), illustrated the crash prevention potential of smart turn signals. In that paper, it was pointed out how neglected turn signals contribute to more crashes than we realized. As a brief recap from that paper related to the quantification of crashes where turn signal neglect may have been a factor:

Excerpt from SAE 2010-01-0744: *"In the U.S., we drive a sum total of about three trillion miles per year for all vehicles. Assuming that turn signals are neglected 10% of the time and that on average, a turn signal is used about once per mile, that translates to a staggering 300 billion neglected turn signal events per year. Now assume that a crash, either a major crash or a minor crash, occurs only once in every 150,000 instances of a neglected turn signal, then it could be concluded that 2 million crashes occur each year in this country due to neglected turn signals (3,000,000,000,000 × 0.10 × 1 divided by 150,000 = 2,000,000). That is likely a conservative figure since observation studies have shown that the neglect rate is in the range of 10% to 35%. Therefore, if a Smart Turn Signal system assured that turn signals are used at all times and the turn signal shuts off appropriately each time, a reduction of 2 million crashes and the prevention of*

thousands of deaths could be realized each year if all vehicles had Smart Turn Signals."

As seen, there was an assumption made regarding the neglect rate of turn signals and the number selected for the computation was an overall 10% neglect rate, or conversely, a use rate of 90%. Alternatively stated, in the general U.S. driving population, when a turn signal should have be used in a driving situation, it was actually assumed to be not used 1 out of 10 times. The reference to "observation studies" in the prior paper was a casual reference to what would become the beginnings of the study that is now the subject of this current paper for 2012. The research in this 2012 paper was pursued in order to remove the assumption of a rate-of-neglect and put statistically significant data into the calculation of crash rates where turn signal neglect was a factor.

BACKGROUND

The study was designed to be simple and indisputable with a high quantity of data points for accuracy: Since turn signals are an outwardly visible form of communication from a driver to surrounding drivers and the only outwardly visible predictor of a vehicle's near-term change in direction, an observation study was designed to simply watch vehicles: When a given observed vehicle would execute a turn, a data point of "yes" or "no" would be recorded in reference to turn signal usage or not. A percentage of neglect rate could then be computed and conversely, usage rates could be computed as well. In the interest of full disclosure, this study was funded solely by RLP Engineering with no external funding from any private enterprise, any government institution, or any educational institute with regards to grants, loans, or sponsorships.

LITERATURE REVIEW

Safety research studies as well as timely implementation of safety systems are priorities in the automotive field, from automotive manufacturers as well as government organizations such as the Department of Transportation. The National Highway Traffic Safety Administration was created in part to foster, sponsor and/or perform research towards the goal of fewer crashes, fewer near misses and generally smoother and more efficient motor vehicle transportation. Fewer crashes result in less property damage, fewer injuries and fewer deaths. The objectives and focus related to the subject of "transportation safety" is an ever-changing landscape and it is research that helps to guide and direct where efforts and investments for safer driving are concentrated. In our society today, despite billions of dollars of funding dedicated to safety research, it is unfortunate that turn-signal-usage-rates research is essentially "not on the radar screen", especially given the importance of turn signals in the prevention of crashes and their contribution to traffic flow.

An extensive search for prior published research was performed on various subjects related to turn signal usage rates, turn signals as a vital active safety feature, turn signals as a crash prevention device, and turn signals related to intelligent transportation systems. Areas of prior research that would have relevance to turn signals were pursued, including vehicle safety, crash proof vehicles, crash prevention, active safety, intelligent transportation, intersection crashes, rear-end crashes, etc. Institutions investigated for available research included, but not limited to the following: U.S. Department of Transportation (DOT), the U.S. National Highway Traffic Safety Administration (NHTSA), USDOT Fatality Analysis Reporting System (FARS), USDOT Research and Innovative Technology Administration (RITA), Insurance Institute for Highway Safety (IIHS), University of Michigan Transportation Research Institute, University of Virginia Center for Transportation Studies, National Traffic Safety Institute (NTSA), National Safety Council (NSC), Truck Safety Coalition, Citizens for Reliable and Safe Highways (CRASH), The National Center for Statistics & Analysis (NCSA), Federal Motor Carrier Safety Administration (FMCSA), all major vehicle manufacturers. Unfortunately, among the noted institutions as well as others not mentioned, there was no published research to be found related to observed turn signal usage rates. This finding was confirmed in a return email from the National Center for Statistics & Analysis stating: "The NCSA is in receipt of your request for information on the actual use of turn signals. Unfortunately, NCSA does not collect this type of data and I am unaware of what agency, if any would be able to provide this type of information." (2).

There is one publication that has some relevance to the subject of turn signal usage rates. This however would not be classified as a formal, scientific study as much as it was a casual survey of 1,000 drivers performed by Response Insurance and made public in 2006 (3). The main conclusion of the survey was that 57% of drivers admit to not using turn signals when they change lanes. The survey also included a query with what appeared to be a limited and somewhat whimsical multiple choice response as to why turn signals were not used. Participant responses as to why they are not used included: "not enough time", "they are lazy", "may forget to turn them off", "it's not important to use turn signals", "because other drivers don't", "they are changing lanes too frequently to bother" and "not using a turn signal adds excitement to driving". While this survey serves to highlight that neglecting turn signals is a problem and may make for an entertaining story, the fact that the study consists of data gathered from asking people questions about their driving habits makes it subject to bias, recollection error and potentially varying levels of honesty from participants. Nevertheless, Response Insurance should be lauded though for recognizing that turn signal usage is not what it should be, and for shedding some light on the subject. Their CEO, Mory Katz is quoted as saying: "The bottom line is that most

drivers are failing to see the importance of using their turn signals" (3), which is an accurate take-away from the study and a statement that many drivers will concur with.

In contrast to pointing out that there is scant research on the subject of turn signal usage rates, it is important to highlight several prominent recent literature publications where turn signal usage rates would presumably be a focus of discussion, yet the subject is conspicuously absent. These NHTSA publications are not singled out in order to denigrate the work or findings of these publications, but to show how an important subject related to vehicle safety is just not on our collective consciousness as it relates to directing safety improvement efforts. The following publications are among those that fail to mention any relationship of safety and crash prevention to the subject of turn signals and how they serve to prevent crashes. These include:

• "Analysis of Fatal Motor Vehicle Traffic Crashes and Fatalities at Intersections", 1997 to 2004″ (2007) (5)

• "The Impact of Driver Inattention On Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data" (2006) (6)

• "National Motor Vehicle Crash Causation Survey" (2008) (7)

• "Analysis of Rear-End Crashes and Near-Crashes in the 100-Car Naturalistic Driving Study to Support Rear-Signaling Countermeasure Development" (2007) (8)

• "Crash Factors in Intersection Related Crashes" - An On-Scene Perspective" (2010) (9)

These 5 cited publications combined consist of more than a thousand pages of vehicle crash reporting, representing countless man-hours and untold costs to compile. They represent major undertakings with pages of data, coding and categorizing of crash causes and contributors, investigations into pre-crash conditions, crash avoidance technologies, etc. In all of these plus many other reports, there is no mention of how turn signals or turn signal neglect relate to causing crashes and affecting crash rates. The only conclusion to be drawn here is that while there is merit to their content, this is a serious and egregious error of omission on the part of these publications with respect to recognizing turn signals as a vital safety feature that serves to prevent crashes. This is an especially tragic oversight, given that the very NHTSA reports cited above claim that 29% of all crashes are rear-end crashes (8), and 40% of all crashes occur at intersections (9). Both "rear end" and "intersection" type crashes are prime situations where turn signals and their proper use are relevant, integral factors relating to crashes.

To summarize the literature search, excluding publications written by the author of this current publication related to turn signals, there are simply no prior publications or studies related to turn signal usage / neglect rates. The phrases "turn signal neglect" and "turn signal neglect rate" currently fail to exist in our vehicle safety lexicon and therefore the concept fails to be recognized as an issue that needs to be addressed.

STATEMENT OF THE PROBLEM

Given that the use of the turn signal is one of the very few active, ongoing means of driver to driver communication, and given that the purpose of the turn signal is to forewarn surrounding drivers of near-term pending maneuvers such that flow of traffic can be maintained and collisions can be avoided, and given that the use of the turn signal is required by law, and given that the use of the turn signal is a 100% voluntary act based on the discretion of the driver, we seek to reveal the turn signal usage rates of drivers on the roadways. The data collected that forms the basis of this paper consists of two forms under the overall heading of "turn signal use". One set of data measured driver's use of the turn signal when executing a turn. The second set of data measured the use of a turn signal to indicate a lane change on a multi-lane roadway. Both forms fall into the category of "lawful use", which is to say that in the jurisdiction of data collection, it is required by law to use a turn signal when executing a turn. Additionally, it is required by law to use a turn signal when executing a lane change.

Therefore, the first hypothesis is as follows: Not all drivers are 100% compliant with the proper use of turn signals when executing a turn as required by law on the public roadways and driver neglect is the root cause. With that as a basis for study, we further seek to determine the quantitative level of turn signal usage for turns and thus, an objective of this study is to determine is the percentage rate of turn signal lawful use / neglect for turns any given driver would encounter from surrounding vehicles on the public roadways.

The second hypothesis is as follows: Not all drivers are 100% compliant with the proper use of turn signals when executing a lane change as required by law on the public roadways and driver neglect is the root cause. With that as a basis for study, we further seek to determine the quantitative level of turn signal usage for lane changes and thus, an objective of this study is to determine is the percentage rate of turn signal lawful use / neglect for lane changes any given driver would encounter from surrounding vehicles on the public roadways.

Another way of stating the problem is this: There exists an automotive safety system known as Turn Signals, which includes both the in-vehicle turn signal system of switches, flash control and lights, as well as a driver who must make a conscious choice and physical effort to use them when appropriate. Assuming that vehicle equipment failure is very rare, the system flaw and "weak link" is the driver and neglect is the cause. Given that the turn signal system includes both the vehicle electro-mechanical components,

lighting, etc. as well as the driver as an integral part of the system, this paper seeks to determine if this system is defective and further to reveal the failure rate of said system.

METHODOLOGY OF THE DATA COLLECTION

The study data was collected in observation form by a singular observer for the entire study. The data is considered dynamic data in a naturalistic setting since the observer was in a vehicle and was simply "driving around" and not fixed at a single location or stationary vantage point at any particular intersection. By utilizing dynamic data, a more comprehensive data set is derived from continuously changing driving situations from multiple locations and multiple driving participants. This results in a more representative "average driving" scenario. The observer had two handheld tally counters. One tally counter was to record the quantity of lawful, proper use of turn signals, while the second tally counter was to record the unlawful neglected use of a turn signal. Each of the handheld tally counters were of a different brand and style such that there was no confusion as to which counter is which when collecting data to record an accurate count and the recording of data could be performed while keeping eyes on the road (If the two tally counters were identical to each other, there would be a risk of "clicking" the wrong counter). A tally of lawful and neglected data was recorded for a single day's drive, then at the end of the day the data for that day was recorded on paper and the tally counters were reset to zero for the next day's data collection. Each data collection day was dedicated to either turn signal use at turns or dedicated to turn signal use for lane changes in order to simplify data collection while the observer was driving. All data points were collected in and around the Dayton, Ohio area, a medium size metro area located in southwest Ohio with a population of approximately 850,000.

Since all data collection was gathered in the state of Ohio, there was a presumption that each observed turning or lane changing vehicle was duty-bound to obey Ohio laws.

The Ohio Revised Code related to turn signals is ORC 4511.39 and it states:

*"When required, a signal of intention to turn or move right or left shall be given continuously during not less than the last one hundred feet traveled by the vehicle or trackless trolley before turning" (*10*).*

ORC 4511.39 further states:

*"Any stop or turn signal required by this section shall be given either by means of the hand and arm, or by signal lights that clearly indicate to both approaching and following traffic intention to turn or move right or left" (*10*).*

For clarification, "turn or move right or left" refers to both turns and lane changes. Also, it is worth noting that either flashing turn signal lights *or* hand and arm signals are both legal to satisfy ORC 4511.39. Data was collected during hours of natural light as well as during the dark. Lane change data was only collected when traffic was considered "medium density", where medium density is generally described as traffic moving at, near or slightly above the posted speed limit with vehicles that would be within reasonable proximity to each other. Thus, lane change data was not collected during stop and go traffic on an excessively congested multi-lane highway, nor was data collected when the roadway traffic was sparse.

Any observation study must examine the ethics of data collection methods before commencing the study. It was concluded that there was not an ethical issue with regards to data collection in this study since all data was obtained from public roadways and observed vehicles were exhibiting a public display of turn signals (or not). Although none of the drivers in the study had knowledge that their behavior was being observed and was part of a study, the reasonable expectation of all drivers is that external vehicle lighting is in plain sight for all within view to see. Thus, there were no issues with privacy identified in this study.

The following criteria were used in the data collection process:

- An observation vehicle was driven in a normal, legal manner on public roadways with the driver of the observation vehicle serving as the observer and keeping all tally counts with the handheld counters, such that the task of data gathering did not distract the driver from the duties of driving.

- The driver of the observation vehicle was diligent to obey all traffic laws regarding turn signal usage for both turns and lane changes in order to remain as neutral as possible to surrounding vehicles during the observation process. The driver of the observation vehicle generally stayed with the flow of traffic speeds so as not to cause surrounding drivers to feel compelled to adversely react to the observation vehicle. The intent was to blend in. For lane changes, a minimum of 5 flashes were used in each case by the observation vehicle.

- The observation vehicle itself was not used as a data point in any of the data collection.

- Observation vehicle was an unmarked, average private vehicle and therefore all surrounding drivers had no indication whatsoever that their turns and/or lane changes were observed and tallied in a study. Tally counters inside the observation vehicle were not visible to surrounding drivers.

• Data collection occurred during random and varied conditions and times, including rain, snow, dry, fog, daylight, nighttime, early, late, weekday, weekend, etc.

• The vehicles counted in the data consisted of trucks, cars, buses, motorcycles, law enforcement vehicles, commercial vehicles, vehicles with trailers, semi tractor-trailers, etc. The vehicles NOT counted in the data consisted of emergency vehicles with emergency lights flashing, mopeds and bicycles.

• Both hand signals as well as flashing turn signal lights were to be counted as "lawful use of signal". It is noteworthy, however, that not a single hand signal was observed in this study at any time.

• No observation data was recorded with respect to the driver or the vehicle: male or female, young or old, cell phone use or not, others in vehicle or not, etc. The only consideration was whether or not the vehicle displayed an appropriate turn signal for the situation. No vehicle identifications of any kind were recorded.

• All data was collected on public roadways. No data was collected on private property, such as a parking lot, where turn signals may or may not be necessary. However, if a vehicle was turning from a public roadway into a private property, then that action was collected as a data point.

• Vehicles with a "stuck-on" turn signal (as can occur for instance on the highway with traditional turn signal mechanisms) were not counted as data points.

• There is a chance, however remote, that the driver may have actuated a turn signal, but a bulb was burnt out or some other malfunction was present on the vehicle's turn signal system. Every effort was made by the observer to look for side or front redundant lights, such as side markers that would indicate turn signal use. If none was seen, then the data point was tallied as a "neglected turn signal". This situation, however was considered to be rare and therefore is not considered to have influenced the outcome.

• If a vehicle was observed turning or changing lanes, but was positioned such that no other vehicles may be close-by or affected by such a turn or lane change, then the observer expectation remained that turn signal use was required in accordance with ORC 4511.39

• Observed turning or lane-changing vehicles this study must be in plain view of the observer, so long as the turn or the lane change is clearly viewed AND the turn signals are in clear view (as would be displayed front, side or rear), regardless of distance or direction from the observer to the observed vehicle. The use of vehicle rear view mirrors for observation was acceptable.

• A single observed vehicle may be observed through multiple turns or multiple lane changes, with each data point representing a distinct turn or lane change and therefore a distinct data point. This may occur for example in the case of travelling within view of a single vehicle for several miles and during that travel observing several separate data point maneuvers.

• If a turn or lane change was observed, but the observer was unclear of the turn/lane change, or the turn signal usage, etc. that could occur due to distance or another vehicle blocking the view, or other uncertainties, then that data point was not counted and was thrown out immediately.

• In the case of observed vehicles turning from a dedicated turn lane (turn arrow painted on pavement or dedicated traffic signal turn arrow light, or turn arrow sign), the observer expectation remained that a turn signal use was required in accordance with ORC 4511.39

• Although clearly specified in ORC 4511.39 requiring a turn signal execution of not less than 100 feet before the turn, for this study, observed turning vehicles were not required to actuate before the 100 feet in order to be tallied as "lawful turn signal use" as a data point. This exception to the law was made in the case of this study in order to achieve a more realistic result. If the "letter of the law" per ORC 4511.39 were to be applied in this study, then it was deemed for the design of this study that the data results would be unrealistically swayed towards greater turn signal neglect. For example, a driver may actuate a turn signal while sitting stopped at a red light, in which case this was deemed "lawful" for this study, even though technically, this action does not satisfy the ORC law requirements.

• In the case of observed vehicles turning, the observer would observe the turn, then simultaneously observe the presence or not of a coinciding turn signal. It was then instantly tallied on the appropriate counter as either lawful compliance or neglected. Each turn data point in this study therefore represents an observed turn that would be deemed as requiring a turn signal.

• In the case of observed lane changing vehicles, the observer would observe the lane change action, then simultaneously observe the presence or not of a turn signal. It was instantly tallied on the appropriate counter as either lawful compliance or neglected. Each lane change data point in this study therefore represents an observed lane change that would be deemed as requiring a turn signal.

• A "lane change" is defined in this study as a vehicle moving from one lane to another, that is, generally defined as crossing a white solid or a white dashed painted roadway line.

• In the case of lane changes, if a vehicle displays a turn signal, but the actual vehicle changing of lanes is not visible to the observer, then this data point is thrown out immediately. This is done to assure accuracy since a lane changing vehicle in the same circumstance with a missing

turn signal indicator would not be seen by the observer. This situation can occur frequently at night.

• A vehicle that changes lanes across several lanes in one singular motion would be counted by the observer as one lane change data point. That is to say that a vehicle may move from a right lane to a center lane to a left lane in one single motion. Turn signal actuation (or not) was considered one single data point. Normal safe practices would dictate however, that one lane change at a time should typically be executed in order to be considered safe.

• A lane change signal was tallied with a minimum of one single flash. Although this could be considered as insufficient actuation of the turn signal for good driver to driver communications, the intent to signal is present and therefore counted, for the sake of this study, as a lawful turn signal usage. Obviously, this is below the common sense minimum standard for signaling, as 3, 4, 5 or more flashes would normally be more appropriate.

With the above criteria established for gathering data for this study, actual on-road data was gathered and documented between January 2010 and October 2011 for both turns and lane changes. 10,000 data points were gathered for turning vehicles and 2,000 data points were gathered for lane changing vehicles during this period. Data gathering was stopped immediately when data point totals reached 10,000 and 2,000 respectively.

By designing this study as a direct observation study with a large number of data points, the utmost in accuracy was achieved. This study would be considered a “blind” study since no drivers in an observed turning vehicle realized that they were actually part of a study. The phenomenon wherein a subject of a study alters what would be their normal behavior simply because they are aware that they are being studied is commonly known as the Hawthorne Effect or Observer Effect. This form of data bias effect was not present in this study since the task of tallying data points was not made known to the observed drivers and the observation vehicle was unmarked. As a contrasting example, if the observation vehicle would have been a marked police patrol vehicle, then the data would have likely been incorrectly biased towards lawful use since drivers alter their behavior towards “obeying the law” in the presence of visible law enforcement. Actions of the observation vehicle were deliberately lawful with respect to turn signals and remained courteous and defensive in driving style in order to remain as neutral as possible. If any influence occurred from the actions of the observer vehicle, however small, it would have been towards surrounding vehicles tending to “follow a good example” or “imitate” good and lawful practices as seen from their perspective. Since there was only one observing individual in this study, there was consistency in judging turns and lane changes and what data points to throw out. Observer bias was non-existent as there are only two possibilities for observed turning vehicles: either a turn signal is on - or it is not.

Furthermore, the observation method utilized in this study yields greater accuracy as compared to a survey for example. In this study where blind observation is used, there is no recollection error from study participants, there is no bias from study participants, there is no opinion from study participants, there is no guessing from study participants, there are no estimations from study participants, there is no “refusal to participate” from potential study participants, there is no “lack of honesty” or “messing with the study” or “lack of seriousness” from participants, there is no measurement error where the act of measuring would cause an inaccuracy in the data, and there is no mistaking a turn signal “on” or a turn signal “off”.

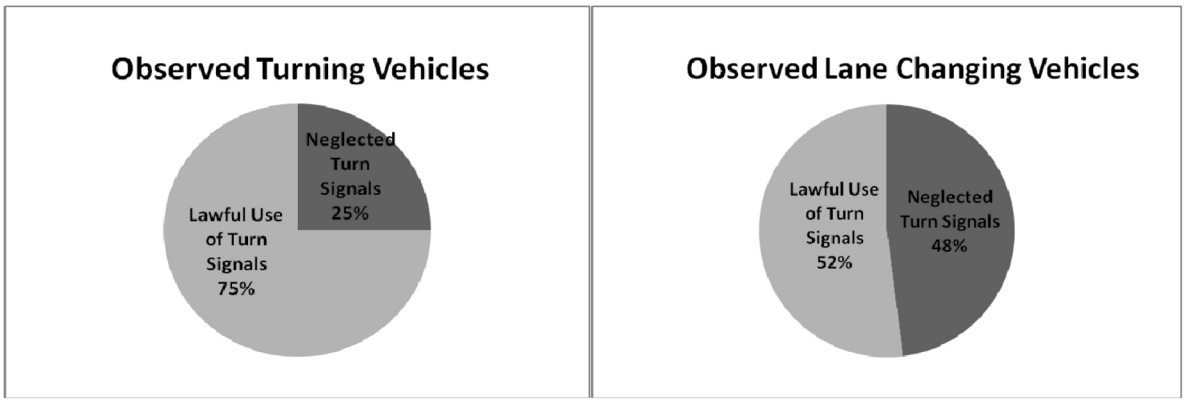
As stated, a total of 10,000 vehicles were observed executing turns as data points. Also stated, a total of 2,000 vehicles were observed executing lane changes as data points. Since this was a sampling study, there is a margin of error associated with the results. There are two possible outcomes for the data points: one outcome is lawful use of the turn signal and the other outcome is unlawful neglected or no-use of the turn signal. These outcomes apply to both turns as well as lane changes. The sampling in this study is considered to be random sampling from a large population. Due to these factors, including the sample size, the margin of error is therefore deemed to be sufficiently small so as to not impact the potential result error in any significant way.

RESULTS

Of the 10,000 data points gathered for observed turning vehicles, 7,457 vehicles were observed exercising lawful use of a turn signal to indicate a turn and 2,543 vehicles were observed *neglecting* the lawful use of a turn signal in a turn. This equates to 74.57% of drivers complying with appropriate turn signal usage when executing a turn, and conversely, 25.43% of drivers failing to comply with appropriate turn signal usage when executing a turn.

Of the 2,000 data points gathered for observed lane changing vehicles, 1,033 vehicles were observed exercising lawful use of a turn signal to indicate a lane change and 967 vehicles were observed *neglecting* the lawful use of a turn signal to indicate a lane change. This equates to 51.65% of drivers complying with appropriate turn signal usage when executing a lane change maneuver, and conversely, 48.35% of drivers failing to comply with appropriate turn signal usage when executing a lane change maneuver.

The results are summarized in the following charts:



SUMMARY AND DISCUSSION

Turn signals are a functional active safety feature designed into all vehicles and they are intended to be used by all drivers at all times as required by law to prevent crashes and to enhance traffic flow. It has been accurately shown in this study that the use rate is as low as 75% for turns and 52% for lane changes; therefore we can conclude that there are crashes that could have been prevented if only an appropriate turn signal were used. In the case of most crashes, there are usually several key factors present that coincide to result in a crash. If just one of those factors is eliminated or corrected, many times a crash is avoided. It is likely the case with many crashes that if a turn signal is used and surrounding drivers are therefore forewarned of that driver's intentions, then actions or countermeasures by surrounding drives can be taken that would simply have avoided the crash, thus creating a total non-incident from what would be a crash with all the implications that are associated with a crash. Every instance of a neglected turn signal is a situation with an increased probability of a crash. Looking at the sheer numbers of these situations created by a 25% turn signal neglect rate; this translates to a staggering 750 *billion* instances of an elevated crash risk occurring every year in the U.S. (3 trillion U.S. miles driven per year times 25% neglect rate times one turn signal required per mile).

In analyzing turn signals and how they are viewed in our culture, we can see that the non-use of turn signals is the somewhat of a running joke as well as the subject of sarcastic bumper stickers, newspaper editorials, etc., and this is most unfortunate. Just as drunk driving was not taken too seriously 30 to 40 years ago as compared to today, the subject of turn signal usage is not generally taken very seriously, but this is a subject that needs to be taken seriously as a significant vehicle safety issue. After all, drunk driving was once a "tolerated nuisance", but not anymore. Until we took a realistic look at what drunk driving was causing did we begin to take a serious look at the subject and recognize it as a problem. Many billions of dollars are spent by private corporations, non-profit institution and our government to investigate how our roadways can be made safer, but there appears to be a near zero effort put forth to understand and/or improve turn signal usage rates. An analogy to seat belt use can be made here: In 1983, seat belts were used at a rate of only 14% (11). In 1984, a government-sponsored campaign was initiated to increase seat belt use. These efforts consisted of in-vehicle seat belt reminders, laws requiring seat belt use, and public service advertising, which all served to increase seat belt use to a level of 85% usage by 2010 (12). In the case of seat belts, they were already installed in all vehicles, but their usage was ignored by too many. We currently have turn signals installed on all vehicles and there are turn signal usage laws, but enforcement of these laws is not consistent and in fact largely ignored by law enforcement. An in-vehicle turn signal reminder for neglectful drivers would serve to greatly increase turn signal usage and thus reduce crashes. Whereas seat belts are a passive safety device which helps to reduce injury and death *when* a crash happens, the turn signal is an active safety device which helps to *prevent* a crash in the first place. In fact, a turn signal used properly raises active safety to another level and not only serves to prevent crashes, but prevents near-crash situations and enhances the flow of traffic.

It is worth revisiting the calculation illustrated in the introduction of this paper to highlight the impact that turn signal neglect has: this time removing the "assumption of turn signal use-rates" and instead using the data from this paper. Also taking an even more conservative approach to the crash rates caused by turn signal neglect, this calculation will use the assumption that getting in a crash based on turn signal neglect is the same equally remote odds as being struck by lightning in the U.S.: There is approximately a 1 in 750,000 chance in the U.S. that a person will be struck by lightning in a given year (13), so the following computation assumes that for every 750,000 neglected turn signal turns executed, that one crash will occur. Therefore 3 trillion miles driven multiplied by one turn signal used per mile multiplied by 25 percent neglect rate times 1/750,000 odds of a crash equals 1 million crashes that could be prevented per year if turn

signals were appropriately used (3,000,000,000,000 × 1 × 0.25 / 750,000 = 1,000,000).

That is a conservative estimate of ONE MILLION CRASHES that could be prevented. In order to illustrate how the assumption of 1 in 750,000 is so extremely conservative with respect to how often a neglected turn signal translates to a crash, consider the following: To say that one crash occurs for every 750,000 neglected turn signals in a turn would be the equivalent of a single driver getting a new driver's license at age 16, then driving 12,000 miles per year while never ever using a turn signal, then driving this way for the next 62 years until age 78 and the "neglected turn signal" practice over all those years and all those miles would cause only one single crash in that period of time. Common sense would dictate that many more than one crash would normally occur in this scenario.

Furthermore, having conducted the study in the Dayton, Ohio area, we must examine what impact this "single-city sampling" has on the resultant data and how this would translate to a nationwide average. The "Allstate America's Best Driver's Report™" (14), which is published every year, claim that Dayton, Ohio drivers are the 16th best drivers out of 193 cities in 2011. The report further states that the relative crash likelihood for Dayton, Ohio drivers is 14% below the national average, implying that Dayton drivers are much safer drivers than the national average and would likely use turn signals more diligently. The inference here is that turn signal neglect rates for turns and lane changes on a national average is actually worse than the 25% and 48% stated in this report.

Therefore, the only conclusion to be drawn is that a figure of one million crashes caused by turn signal neglect is ultra conservative. A more realistic crash rate would be appropriate to examine: Assume that the odds of a crash from a neglected turn signal are 1 in 500,000. That would translate to 2 million crashes per year. Odds of 1 in 250,000 would thus contribute to 3 million crashes per year, etc. Combined with national turn signal neglect rates that would be higher than the figures in this report, suffice it to say that *millions* of crashes can be prevented by eliminating turn signal neglect.

The subject of distracted driving has gained widespread national attention lately, with U.S. Secretary of Transportation Ray LaHood leading the charge, calling it an "epidemic" (15). Distractions are nothing new to driving, but cell phones and texting have been highlighted as growing problems that have potentially made the problem worse. There are many published examples of senseless crashes, injuries and deaths being blamed on cell phone use and texting, and all are indeed tragic. To illustrate the problem, Secretary La Hood cites numbers from a NHTSA published report, entitled "Distracted Driving 2009" (16). The report states that 959,000 crashes occurred that involve driver distraction in 2009. Comparing the numbers from the NHTSA distracted driving report to the turn signal neglect numbers of more than a million crashes that are the subject of this study; one can see that the turn signal neglect issue is a problem worse than distracted driving. If the Secretary of Transportation calls distracted driving an epidemic, then it would follow that neglected turn signals would also be classified as an epidemic as well. The Department of Transportation will spend $330 million in 2012 on the "ongoing campaign against America's distracted driving epidemic", $7 billion to "promote seat belt use, get drunk drivers off the road, and ensure that traffic fatality numbers continue falling from historic lows", and $17.5 billion to "double the investment in highway safety infrastructure spending and safety programs" (17). Meanwhile, the DOT's total expenditure in 2012 on the turn signal neglect epidemic will be zero.

As a society, we simply will not tolerate known defects in our vehicles, especially when it comes to safety related functions. When a defect is discovered and confirmed, the public demands a fix, NHTSA would likely issue a recall, and manufacturers give an all-out effort to expediently implement a resolution. As stated previously in this paper, the turn signal safety system in a vehicle consists not only of the turn signal equipment built into the vehicle, but also includes the driver, who must be relied upon to actuate the turn signal by moving the steering column lever when appropriate to communicate a pending turn or lane change. The system simply does not work without input from the driver. Therefore it can be concluded that this vehicle safety system known as turn signals has a reliability rate of 75% for turns, and 52% for lane changes, based on the results of this study. This resultant outcome can only be described as "defective" and the situation begs for a solution when the numbers are revealed. This system is not just a defect on one model, but it is a defect on every vehicle sold, year after year. If any other vehicle safety system in a vehicle were to have such poor reliability rates, then there would be a public uprising calling for a resolution and NHTSA would demand an implemented solution plan from manufacturers. But the existing turn signal defects are currently overlooked.

As a way of illustrating how important the turn signal is, assume for a moment how these reliability numbers would look as applied to brake lights: Imagine if every vehicle on the road today were such that brake lights came on randomly only 75% of the time whenever the brake pedal was pressed. All vehicles would be constant targets for being crashed into every time that the brake lights failed to come on. It would be hard to imagine how much higher the crash rate would be and this would simply be a situation that would not be tolerated. The brake light systems built into vehicles today are virtually 100% reliable: When the brakes of a vehicle are actuated by the driver, the brake lights are illuminated, thereby alerting following drivers that the vehicle is slowing down or

stopping. Turn signals serve to prevent rear end collisions as well, that is, when they are used by the driver. A National Transportation Safety Board Special Investigation Report states: "According to a 1992 study by Daimler-Benz, if passenger car drivers have a 0.5 second additional warning time, about 60 percent of rear end collisions can be prevented. An extra second of warning time can prevent about 90 percent of rear-end collisions" (18). While a following driver can react to the onset of a brake light seen ahead, the addition of the turn signal is an additional level of communication to a following driver to understand the intent of the vehicle's next move and thus better respond to the slowing vehicle. The "extra second of warning time" when a vehicle ahead is turning can be in the form of a turn signal, thereby greatly reducing the overall chance of a rear-end collision by as much as 90%. When properly executed, the turn signal effectively acts as a pre-brake warning to a following driver. If the brake light is a visual rearward communication of vehicle deceleration, then the turn signal is as well. Whenever a vehicle is going to execute a turn or change lanes, the driver in a following vehicle *deserves* and should *expect* an appropriate turn signal from that vehicle. We should strive for nothing less than 100% reliability from our turn signals from every vehicle, at all times.

The subject of Intelligent Transportation Systems (ITS) and its implementation and eventual success is critically dependent on turn signal use. The ITS community speaks of a "crash proof car" and improved traffic flow. ITS is based upon vehicle to vehicle communications as well as vehicle to infrastructure communications. In this proposed plan, all moving vehicles and critical infrastructures would communicate and broadcast "Here I Am" realtime messages such that ideally, all crashes could be prevented by automated proactive avoidance. These measures only serve to *react* to a given situation, with no prediction of future actions from any given vehicle. If all drivers were behaviorally conditioned to use turn signals appropriately nearly all of the time, these systems could depend not only on the "Here I Am" data, but could also utilize reliable higher level data communicating "And Here's What I Am Going To Do Next", which is to say it would communicate a future intent to other vehicles. This transforms an ITS from a reactionary system into a more proactive system that predicts and adjusts accordingly. The 70 year old flashing light turn signal is one of the original intelligent transportation systems and crash prevention systems dating back decades before the concept of "smart highways" was conceived. The turn signal is today as it was more than 70 years ago, by definition, a driver-to-driver intelligent transportation system - that is to say when it is actually used by drivers. An ITS must be rolled out with full consideration of turn signal status of any given vehicle and any given driver of said vehicle must reliably and appropriately utilize the turn signal. Given that turn signal use is currently not reliable on a wide scale, we must first understand the nature and scope of turn signal neglect and then address the issue in terms of how to resolve this epidemic. Any form of an intelligent transportation system is not complete without a turn signal system that is reliable on a wide scale.

The study that is the subject of this report intentionally overlooks the "why" of turn signal neglect, to be left to another study. We can however, speculate what may occur in the mind of the driver that neglects the turn signal: It may be simple carelessness (it takes effort or it is forgotten or I just don't care, etc), driver distractions (the mind of the driver is divided between the task of driving and some other non-driving related cognitive task), driver physical preoccupation (cell phone in one hand and a steering wheel in another hand and no hands available to hit the turn signal lever), driver skill level (It's all some drivers can do to just get the car from point A to point B - using a turn signal just does not come to mind), lack of a perceived personal benefit on the part of the driver (why do I need to signal since I already know what I am going to do?), the lack of a direct cause-effect of not using turn signals (most of the time, you are ok and do not crash). Also this study intentionally overlooks the "who" subcategory of turn signal neglect. There may be insight to be gained in tracking young or old, male or female, etc. with regards to turn signal neglect, but that will be saved for a future study. Additionally, all data for this study was gathered in one metropolitan area: Larger cities or possibly smaller cities may yield different neglect percentages, possibly higher or lower, but this too will be saved for a future study. It is the "what" of this study that should raise interest in the automotive safety community: The number of crashes that can be prevented by rectifying turn signal neglect numbers in the millions. Also, countless deaths can be prevented as well.

It is worthwhile noting in this setting that a solution to prevent turn signal neglect is a currently available technology that would add little or no cost: Smart Turn Signals (STS) have been developed that assure that turn signals are on when they should be on and off when they should be off. In addition to preventing a stuck-on turn signal, Smart Turn Signals have a feature known as Turn Signal Assist (TSA) whereby a vehicle's turn signal usage in turns is measured and tracked. If a driver repeatedly neglects the use of a turn signal when executing turns, then a dashboard message is displayed to remind the driver to use turn signals next time, thereby improving the driver's turn signal use over time. The message would remain on for about 10 seconds and would read "USE SIGNAL NEXT TURN". The system is transparent to drivers who diligently use turn signals most all of the time, whereby they would never generate a dashboard message in a lifetime of driving, even if a turn signal was occasionally missed. Conversely, drivers who repeatedly neglect to use turn signals will quickly rectify their bad habit and become conditioned to use turn signals appropriately. In fact, the habit of using a turn signal carries over to other vehicles driven: It just makes you a better driver. The system can be

incorporated into today's new vehicles for no added cost since the sensors required are already integrated into all vehicles. Full details of this patented Turn Signal Assist system are outlined in the SAE report publication 2009-01-0551(4). This Turn Signal Assist system can be compared to seat belt reminders in vehicles in that it simply provides a reminder for something that could save your life and that you are obliged by law to do. The difference here is that seat belt use is argued by some as being a personal choice, whereas the use of a turn signal is the duty of every driver to all surrounding drivers in order to achieve a level of predictability and improved traffic flow. Lane Departure Warning is also analogous to Turn Signal Assist: If you stay on the road, the Lane Departure Warning stays silent and in the background, but if you steer your vehicle outside the bounds of your lane, a warning is presented to the driver. Proper turn signal use remains a key element of the privilege of driving. Just as stopping at red lights and stop signs is a duty that prevents crashes, so too is it the duty of all drivers at all times to exercise appropriate use of turn signals.

The last consideration to be made with Smart Turn Signals and Turn Signal Assist is that of unintended consequences. It is hard to imagine that the proper use of a turn signal would result in a situation whereby a driver would abuse or over-use the turn signal. It cannot cause reckless driving, or speeding or any other abuse. In all cases, it simply makes you a better driver. A turn signal's overall intent is that it should be “on” when it should be “on” and “off” when it should be “off”. Turn Signal Assist assures that turn signals are “on” when they should be “on” and no more neglected turn signals. Smart Turn Signals assure that turn signals are “off” when they should be “off” and no more “stuck-on” turn signals. While all would agree that seeing all other vehicles on the road with accurate and timely turn signals is a good thing, some might argue that they would be annoyed at having their own vehicle correcting their driving habits by seeing a display instructing on turn signal use. You as a driver have the duty by law to use the turn signal. This is an obligation that goes along with the privilege of having a driver's license and sharing the public roadways, and is just common courtesy owed to your fellow drivers. In fact, one consequence of a smart system is that a person may actually avoid a traffic ticket. One could imagine that a fleet owner or rental car company would be happy to know that turn signals are properly displayed. Also fewer crashes will result in reduced insurance rates.

CONCLUSION

The data presented here should serve as a wake-up call to all citizens, vehicle manufacturers, research institutes and government entities that are involved in vehicle safety. A greater focus is needed at the highest levels to create an overall awareness that turn signal neglect is an injury and death problem, as well as a property damage problem, and that the in-vehicle technology to combat this is available and adds no cost. Turn signal neglect is a problem that causes more crashes than distracted driving and if “neglect” of the use of turn signals is the message in this study, then “neglect of the neglect” is the story of the automotive safety community. This subject can no longer be neglected from a research standpoint, a funding standpoint, or an implementation standpoint. There is no reason to ignore the problem of turn signal neglect as a non-issue and no reason to delay the implementation of Smart Turn Signals in all of our cars and trucks. In all of our many billions of dollars of expenditures as a nation devoted to research on vehicle safety, it is quite shocking that none of our research studies consider the subject of turn signal neglect, nor do these publications even mention that the lack of a turn signal from driver neglect could be a factor in crashes. Considering that there are *millions* of crashes that could be prevented with appropriate turn signal use, it is simply unacceptable and is a gross oversight that previous vehicle safety studies fail to address the use of turn signals as a crash prevention measure. This is especially disturbing when a technology-based solution to address the issue of turn signal defects and turn signal neglect is at hand. If we as a society want to significantly reduce property damage, injury and deaths, we must take a serious collective look at the subject of turn signal usage rates and strive to improve these rates such that all drivers use turn signals appropriately at all times, and thus make our roadways safer for all. The remedy of Smart Turn Signals with Turn Signal Assist is simple, effective, adds no cost, adds no weight, and merely makes full use of safety equipment which is already installed on all vehicles. If we accept that the very concept of having turn signals on vehicles is a good idea, then making them work for all and at all times in all places is vital to reducing crash rates. The present turn signal system is a defective one and failure rates of 25% and 48% cannot be tolerated.

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ABREVIATIONS

OHC
Ohio Revised Code

NHTSA
National Highway Traffic Safety Administration

DOT
Department of Transportation

NSC
National Safety Council

FARS
Fatality Analysis Reporting System

CRASH
Citizens for Reliable and Safe Highways

RITA
Research and Innovative Technology Administration

NCSA
National Center for Statistics & Analysis

FMCSA
Federal Motor Carrier Safety Administration

IIHS
Insurance Institute for Highway Safety

NTSA
National Traffic Safety Institute

ITS
Intelligent Transportation Systems

STS
Smart Turn Signals

TSA
Turn Signal Assist

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