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Review of policies and incident duration associated with disabled and abandoned vehicles

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Abstract

Incident duration analysis, questionnaire survey results and literature review related to disabled and abandoned vehicles from different states in comparison to those experienced in Tennessee are presented in this paper. The findings are part of the study that examined the impact of some sections of Tennessee laws regarding removal of abandoned and disabled vehicles. A comprehensive search of literature was undertaken to uncover both published and unpublished papers and reports on previous efforts related to disabled and abandoned vehicle incidents. A survey questionnaire was synthesized to solicit experience, policy and practices related to disabled and abandoned vehicle incidents. The study found that, the abandoned and disabled vehicle incidents are problematic in other states as in Tennessee. It was found that the laws and regulations governing abandoned and disabled vehicles vary from one state to another and sometimes by counties or cities within the same state. Most states seem to be satisfied with their current laws regarding removal of abandoned/disabled vehicles; however, there have been law changes in some states to facilitate such incidents management. The time taken to tow abandoned and disabled vehicles in many states was found to range between 24 to 48 hours after the incidents. The average disabled and abandoned incident durations in many states ranges between 30-60 minutes while in Tennessee the average incident duration is 57 minutes. Statistical tests were utilized to draw conclusions on the impact of different factors related to abandoned and disabled vehicle incidents. Based on the findings, the study concluded that the 48 hours time range required by the Tennessee laws for the removal of disabled or abandoned vehicles has no significant negative effect on the traffic safety and operations in the state

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1. Introduction

Congested highways are known to be dangerous to the motorists as well as to the incident responders. According to unpublished report from Tennessee Department of Transportation (TDOT) on Incident Management experience, it is hypothesized that 25% of the congestion is caused by traffic incidents. It is also believed that one minute of congestion equal five minutes of delay and 14%-30% of freeway crashes are actually secondary crashes generated as a result of traffic incidents. For the past five years, the report from TDOT Region III Smartway Traffic Management Center has shown that incidents on Tennessee freeways have been dominated by disabled or abandoned vehicles. For instance, from 2005 to 2009, there were 108,911 incidents reported, in which 78,105 (72%) of them were due to disabled or abandoned vehicles. Additional analysis showed that disabled and abandoned vehicle incidents increased substantially from year 2005 to 2010 at an average of 7% per year. To remove disabled or abandoned vehicles on access controlled facilities, relevant Tennessee Code Annotated requires the agency causing its removal to make a reasonable effort to allow the owner of the vehicle to arrange for its removal and give due consideration to having the vehicle towed..... It is hypothesized that the longer the duration of disabled or abandoned on highways, the higher the probability of secondary incidents or crashes. The longer the disabled or abandoned vehicle along the highways, the higher the likelihood of secondary collisions or other safety related incidents to be generated. The safety impact resulting from crashes and injury severities associated with these incidents have not been fully examined. Furthermore, the impact of Tennessee Code Annotated sections regarding abandoned vehicles to crash frequencies, type and injury severities have not been evaluated.

This paper therefore presents the portion of the study findings from the comprehensive literature reviews conducted and the questionnaire survey sent to all states (though only 20 states responded). Literature review was undertaken to uncover both published and unpublished technical papers and reports on previous efforts of this kind. The review covered library holdings, databases, and gateway services. The purpose of the review was to determine highway sections, jurisdictions, states, regions, and type of incidents, traffic variables in relation to abandoned and disabled vehicles as experienced in other cities or states and compare with those in Tennessee. A survey questionnaire was synthesized and sent to all states to solicit published and unpublished policy, data and other information related to this subject. The personnel targeted to respond to the survey questionnaires were traffic management agencies, safety engineers, traffic engineers, planners and any other personnel in equivalent capacity within the state.

2. Literature review

Abandoned vehicles can be attributed to different factors. The study by Maxfield (2008) on abandoned vehicles highlighted generalized factors to be considered for classifying a vehicle as abandoned. The study stated that, the length of time at location, the condition appearance, missing or outdated license plates and the location (parked on public streets or other public property) are significant factors to consider for classifying a vehicle as abandoned. Smith et al (2003) supported the above study in the research conducted in England on the impact of the end of life directive and new initiatives on likely future trends. The study listed some factors that may contribute to abandoning vehicles on the streets and the highways. The list included cost of operating and disposing of vehicles which are cost of repair and insurance, cost of safety and emissions compliance, cost and convenience of legitimate disposal, declined value of scrap metal and natural disasters. Other mentioned factors include, auto theft, insurance fraud, long-term or unlimited parking in public facilities and auctions of low-value vehicles. According to NCHRP (2003) "hazard or obstruction" includes but not limited to any vehicle that is parked so that any part of the vehicle extends within the paved portion of the travel lane or any vehicle that is parked such that any part of the vehicle extends within the highway shoulder or bicycle lane. Abandoned vehicles, though not directly blocking the lanes, they cause confusion to drivers whether the vehicles on the shoulder are trying to enter the lane. According to NTIMC (2004) abandoned vehicles causes drivers not only to slow down but also sometimes to crane their heads to get a view of the spectacle, taking their eyes off the roadway ahead thus creating a lot of issues with traffic flow and also accidents.

2.1. Abandoned Vehicle Laws in Major Tennessee Cities

Definition and laws governing abandoned vehicles vary among major cities in Tennessee, Table 1. The city of Memphis code of ordinances section 14-4-2 (City of Memphis Codes) define abandoned vehicle as any motor vehicle which is wrecked or partially dismantled or inoperable for a period often ten days. Nashville Metropolitan Code of Laws section 12.08.210 (B) (Nashville MPO Codes) categorize abandoned vehicle as a motor vehicle that is over four years old including any contents of that vehicle, that is left unattended on public property for more than ten days, or a motor vehicle that is in an obvious state of disrepair and is left unattended on public property for more than three days. The city of Knoxville define abandoned vehicle as 1) a motor vehicle that is left unattended on public property for more than thirty days, 2) any motor vehicle that has remained illegally on public property for a period of more than forty-eight hours, or 3) a motor vehicle that has remained on private property without the consent of the owner or person in control of the property for more than forty-eight hours. City of Chattanooga (City of Chattanooga Codes) define abandoned vehicle as any vehicle or part which is left unattended on public or private property for more than ten days, or a vehicle that has remained illegally on public property for a period of more than forty-eight hours, or a vehicle that has remained on private property without the consent of the owner or person in control of the property for more than forty-eight hours. Chattanooga and Knoxville laws are similar to those of the state while Memphis and Nashville allow much longer than the state thresholds.

Table 1

Major Tennessee Cities Laws for Abandoned Vehicles

County or City	Time Allowed Unattended		Code Number	Text from State Laws & Codes
	Hours	Days		
Chattanooga	48	2	24-341 (City of Chattanooga Codes)	Abandoned vehicle shall mean any vehicle or part thereof which is left unattended on public or private property for more than ten (10) days, or a vehicle that has remained illegally on public property for a period of more than forty-eight (48) hours, or a vehicle that has remained on private property without the consent of the owner or person in control of the property for more than forty-eight (48) hour
Knoxville	48	2	17-122 (City of Knoxville Codes)	Any motor vehicle that has remained illegally on public property for a period of more than forty-eight (48) hours
Metropolitan Nashville	72	3	12.08.210 (Nashville MPO Codes)	...that is left unattended on public property for more than ten days, or a motor vehicle that is in an obvious state of disrepair and is left unattended on public property for more than 3 days.
Memphis	240	10	14-4-2 (City of Memphis Codes)	... any vehicle which is wrecked or partially dismantled or inoperable for a period often (10) days. ... if it has remained inoperable or partially dismantled or if the owner has relinquished dominion or control of such vehicle for ten days.

2.2. Abandoned and Disabled Vehicle Incidents as Experience from Other States

Apart from Tennessee, abandoned and disabled vehicles problem are also experienced in other states. The State of North Carolina completed a five year study (Metro Atlanta, 2012) in 2005 on abandoned vehicles related crashes involving 1300 vehicles resulting in 47 fatalities and over 500 injuries. In the state of Ohio, the disabled vehicles on the road side are major safety concerns contributing to accidents occurrences (Ohio DOT, 2007). From 2000 to 2005 a total of 3,652 crashes occurred on the Ohio interstate highway system which involved collisions with stopped or parked vehicles on a travel lane or shoulder. The study by Smith et al. (2003) reported that in the state Virginia crash database, disabled vehicles are by far the most frequent type of incident, accounting for 72.9 percent of all incidents in the database, and account for 8.2% of all accidents reported. In another study, Parham et al. (1999) found that

nearly 80% of all the incidents in the state of Texas were attributable to disabled vehicles. The study further indicated that 80% of those disabled vehicles were on the shoulder for an average of 15 to 30 minutes, which caused approximately 100 to 200 vehicle-hours of delay during the peak periods. The remaining 20% of disabled on travel lanes caused an average of 15 to 30 minutes and 500 to 1000 vehicle-hours of delay during peak hours.

Incident data analysis by Raub (1997) which covered vehicular crashes, fires, disablements, traffic enforcement, and other traffic related for the year 1997 in northern Chicago, found that the crashes represented 35% of all incidents of which 27% were caused by the presence of disabled vehicles. The report on the Highway Safety Desk Book (2004) showed that over a 10 year period, Washington State experienced more than 3,000 collisions involving abandoned vehicles, among those collisions, 40 resulted to deaths and 1,774 injuries, with total estimated economic loss of nearly \$36 million. In another research on the accidents involving vehicles parked on shoulders of access controlled highways from 1985 to 1987 in Kentucky (Agent et al. 1990), it was found that the percentage of all accidents on interstates and parkways involving a vehicle on the shoulder was as low as 1.8%. The same study also found that although the percentage of all accidents on interstates and parkways involving a vehicle on the shoulder was low as 1.8%, their percentage of fatal accidents was significant at 11.1% with large number involving abandoned vehicles. According to Parham et al (1999), in Minnesota, 13% of all peak period accidents on one Minneapolis freeway were caused by a previous incident. The study indicated that, 20% to 30% of freeway pedestrian fatalities were the result of motorists wandering away from the disabled vehicles to obtain mechanical assistance. The Southeast Michigan Council of Governments (SEMCOG, 2001) conducted a research on the impact of 48 to 24 hours abandoned-vehicle legislation in 2001. The study found that there was a decrease in the number of the towed vehicles which implied that there was decrease in the number of the abandoned vehicles. Based on the positive effect, the study further recommended vehicle towing period to be reduced from 24 to 12 hours. The caution was however raised on the 12-hour tow period due to the potential of increasing the police workload as well as for the towing companies towing the abandoned vehicles (Metro Atlanta, 2012). Traffic incidents which generate secondary incidents especially traffic crashes sometimes lead to prolonged legal issues (Rahim, 2003).

2.3. State Laws Regarding Removal of Abandoned and Disabled Vehicles

Table 2 summarizes list of states with the time limit permitted for abandoned or disabled vehicles to remain unattended. As shown, New Mexico has the longest time period before the vehicle is considered to be abandoned and defines abandoned vehicles as those which have been left unattended on either public or private property for at least 30 days (720 hours). The state of Alabama allows 7 days, Mississippi and Georgia both have 5 days time period before the vehicle is tagged as abandoned. Table 2 also shows that five states, Maine, Nevada, Oregon, West Virginia and Wyoming don't have a defined time limit for abandoned vehicles. In Oregon, for instance, if the vehicle is unattended, the officer may cause the vehicle to be towed and stored at the owner's expense. Furthermore, Table 2 lists California, Illinois and Delaware as three states with least time period elapses before the vehicle is classified as abandoned. In the state of California, if a vehicle is left unattended, is stopped or parked for more than 4 hours upon the right of way of a freeway that has a full control of access and no crossing at grade and the driver, it is categorized as abandoned. The state of Illinois has 10 hours and Delaware 12 hours.

Table 2
State Laws for Abandoned Vehicles

State	Hours Allowed Unattended	Code Number
Alabama	168	Code of Alabama
Alaska	48	Alaska Statutes
Arizona	48	Arizona State Legislation
Arkansas	24 or 48	Arkansas Statutes and Codes
California	4	California Vehicle Codes
Colorado	48	Colorado Division of motor vehicles
Connecticut	24	Connecticut Division of motor vehicles
Delaware	12	Delaware Codes
District Of Columbia	48	District of Columbia Statutes
Florida	24	Florida Division of Motor Vehicles
Georgia	120	Georgia Codes
Hawaii	24	Hawaii State Legislature
Idaho	24	Idaho Statutes
Illinois	10	Illinois Codes
Indiana	72	Indiana Codes
Iowa	24	Iowa Codes
Kansas	48	Kansas State Legislature
Kentucky	72	Kentucky Statutes
Louisiana	24	Louisiana Motor Vehicle Statutes
Maryland	48	Maryland Codes
Massachusetts	72	Massachusetts Laws
Michigan	48	Michigan Vehicle Codes
Minnesota	48	Minnesota Statutes
Mississippi	120	Mississippi Legislature
Missouri	10 or 24	Missouri Revised Statutes
Montana	48	Montana Legislature
Nebraska	24	Nebraska Statutes and Codes
New Hampshire	24	New Hampshire Statutes
New Jersey	48	New Jersey Motor vehicle Commission
New Mexico	720*	New Mexico Statutes and Codes
New York	24	New York Vehicle & Traffic
North Carolina	24	North Carolina Statutes
North Dakota	48	North Dakota Legislature
Ohio	48	Ohio Codes
Oklahoma	48	Oklahoma Statutes
Pennsylvania	48	Pennsylvania Codes
Rhode Island	48	Rhode Island Statutes
South Carolina	48	South Carolina Codes
South Dakota	48	South Dakota Statutes
Tennessee	48	Tennessee Codes
Texas	48	Texas Codes
Utah	48	Utah Legislature
Vermont	48	Vermont Laws
Virginia	48	Virginia Codes
Washington	24	Washington Legislature
Wisconsin	72	Wisconsin Legislature

2.4. Abandoned and Disabled Vehicles in Other Countries

Not only in United States, the abandoned and disabled vehicles incidents is a global problem. For instance in China, one study (Hu et al. 2007) discussed the expressway roadside safety problems using the historical accident recorded from the year 2002 to 2004. The analysis showed that there were 97 collisions with the parked vehicles on the shoulder which accounted for 3.4 % of the total accidents. The aggressive public information campaign to raise awareness of the abandoned vehicle problem was also done in England in November 2007, whereby the Highways Agency (Public Consultation, 2007) organized the public consultation to allow traffic officers to remove broken down or abandoned vehicles from the road networks. The proposal for the new legislation aimed to provide traffic officers with similar powers to the police to request or remove from the road network abandoned and broken down vehicles causing an obstruction or danger to the road users.

2. Disabled and Abandoned Vehicles Incidents by Numbers

The study utilized incident data monitored by Traffic Management Center (TMC) covering Tennessee Department of Transportation (TDOT) Region 1 and Region 3. Region 1 TMC covers I-640, I-40, I-140, I-275, I-75, SR 115 and SR 162 mainly in Knox County while Region 3 covers I-40, I-440, I-65, I-24, Ellington Parkway, Briley Parkway, and Vietnam Veterans Parkway within Davidson, Sumner, Williamson and Wilson Counties. Region 3 incident data ranged from 2004 to 2010 whereas those from Region 1 ranged from 2005 to 2010. In addition to the incident data, crash data was gathered from Tennessee Department of Safety (TDOS) as well as from Tennessee Roadway Information Management System [TRIMS] database monitored by TDOT. Roadway geometry, land use and traffic characteristics for each of the study highways were downloaded from the TRIMS database. The incident duration is calculated as the difference between the starting and clearance time (Chimba et al. 2014). The mean abandoned and disabled vehicle incidents duration in Tennessee was found to be 57 minutes excluding zero duration incidents. In comparison, the average incident in the state of Minnesota was reported as 31 minutes, 45 minutes in New Jersey and 60 minutes in North Carolina (per survey findings) (Chimba et al. 2014). Figure 1 shows that almost 85% of all the disabled vehicle incidents lasted within 30 minutes before being cleared (87% for abandoned vehicle related incidents). That indicates most of the disabled vehicle incidents were immediately cleared compared to abandoned incidents which took a little more time to be cleared. Literature showed the mean incident duration in Washington State as 136 minutes (Nam and Mannering 2000) and 78 minutes in Ohio (Lee and Fazio 2005).

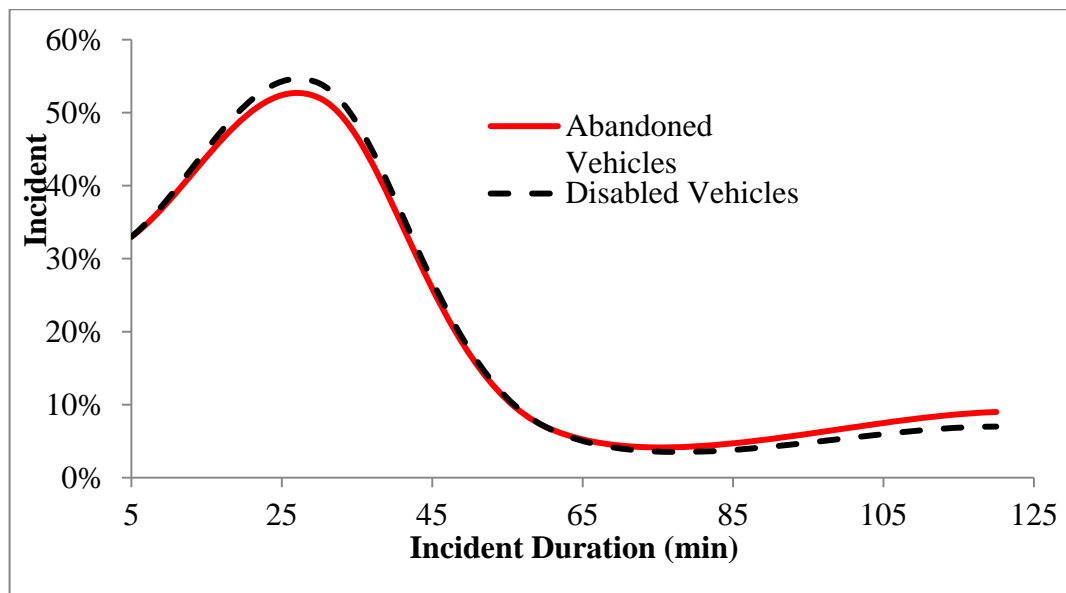


Fig. 1. Percentage distribution of incident durations

3. Findings from the questionnaire survey

A questionnaire survey was prepared to obtain information on freeway incidents, studies, publications and other related information from other state's department of transportation (DOT). The survey was targeted to traffic management agencies, safety engineers, traffic engineers, planners and any other personnel in equivalent capacity. The objective of the survey was to examine how other states handle disabled and abandoned vehicle incidents, and how these incidents affects safety and traffic operation in those states compared to Tennessee. The questionnaire also asked if there was anything TDOT could learn from these states. Some of the survey questions were as listed below:

- Does an incident management manual exist for your jurisdiction?
 - *If yes, does it include instructions for removing abandoned/disabled vehicles? Yes/No*
- Has a study of incident related to safety or congestion been conducted for your jurisdiction or institute? Yes/No.
 - *If yes, is it possible to obtain a copy of the study report/paper/presentation? Yes/No*
- Does your jurisdiction have guidelines of how to identify secondary crashes? Yes/No.
 - *If yes, which element do you consider? the time frame between incidents, the distance between two incidents, queue lengths built from the primary incident, other pre-defined criteria or other methodologies*
- Where disabled vehicles are typically relocated to? (Check all that apply) .
 - *Nearest shoulder , Nearest ramp, Accident investigation site, Private towing company yard, repair facility*
- Does your jurisdiction have laws guiding the removal of vehicles from the right-of-way on freeways? Yes/No.
 - *If yes, what is the number of hours or days that vehicles can stay before considered abandoned?*
- Is towing disabled and abandoned vehicles a problem in your jurisdiction? Yes/No.
- Has the law changed recently to facilitate dealing with highway incidents? Yes/No.
 - *If yes, when did the current law take effect?*
 - *If yes, why did the law change? to reduce secondary crashes, to reduce congestion , to keep shoulders clear for emergency response units, other reasons*
- If the abandoned/disabled vehicles laws exist, indicate the degree of your agency's satisfaction with the law.
 - *Very satisfied, Satisfied, Unsatisfied, Very unsatisfied (would like some changes)*
- Should the time period for abandoned vehicles be extended, shortened, or kept the same?
 - *reduced to—hours, extended to—hours , kept the same*
- What is the average incident time in your jurisdiction?

3.1. Survey Results

Though the survey was sent to all fifty states, only twenty states responded to the questionnaire survey. Among twenty states which responded, only twelve do segregate their incidents by type such as disabled or abandoned vehicles. The findings from those twelve states are presented in the next sections. After examination of the responses from those twelve states, it was determined that several states were experiencing almost the same problems as was for Tennessee. However only 22% states conducted research study related to traffic incidents while 78% of the states surveyed haven't done any related study. Another question of interest was to determine whether or not other states have an incident management manual and instruction for the abandoned and disabled vehicles compared to Tennessee which doesn't have. Survey showed that 60% of the states which responded have abandoned and disabled vehicle incidents management manual while 40% does not have.

3.2. Where Disabled and Abandoned Vehicles are relocated to

The site for relocating abandoned and disabled vehicles is an important element in the process of clearing related incidents. Incident duration varies depending on the means in which the disabled and abandoned vehicle is to be removed. One of the survey questions was structured as where disabled or abandoned vehicles are typically relocated to, with response options listed as: 1) to the nearest shoulder, 2) nearest ramp, 3) accident investigation site, 4) private towing company yard, 5) vehicle repair facility or 6) others. Table 3 shows the survey results where 78% of the states surveyed prefer private towing company as a means for removal of disabled vehicles, followed by moving them to the nearest shoulder (56%), moving them to the nearest ramp area (44%), and to the accident investigation site (44%).

Table 3

Abandoned and Disabled Vehicles Relocation Sites

	Nearest Shoulder	Nearest Ramp	Accident Investigation Site	Private Towing Company	Vehicle Repair	Other
Kansas				✓		
Minnesota	✓	✓	✓	✓		
Nevada						✓
New Jersey	✓	✓	✓	✓	✓	
North Dakota	✓			✓		✓
Oregon	✓	✓	✓	✓		✓
Arkansas						
Colorado	✓	✓	✓	✓		✓
North Carolina				✓		

3.3. Laws Guiding the Removal of Vehicles from the Right-Of-Way and the Time Limits

Every state surveyed responded that they have law(s) defining the time limit before the abandoned or disabled vehicles are removed, Table 4. The survey showed that 4 out of 12 states (33%) have a 48 hours time limit for a vehicle to stay on the shoulder or median, and another 25% allows 24 hours. The response received from the state of Minnesota showed the time limit of 4-hours for rural areas and 2-hours for urban. This was contradictory from the 48 hours time limit listed in the Minnesota state code (Table 2) which indicates the state department of transportation might be using stricter enforcement compared to the state law limits. The same case was observed for the state of Virginia which indicated 24 hours time limit compared to 48 hours required by state law. Washington State time varies, which might be based on the county or city bylaws. The states of Nevada, North Dakota, and Oregon didn't indicate the required time limit. Almost every state that responded indicated willingness to keep the laws as they are now.

Table 4

Time Limitation Before Vehicle Is Considered Abandoned

State	Have Removal Law	Hours vehicle can Stay on the Shoulder or Median	Current Time for Abandoned Vehicles
Kansas	Yes	48	Kept the Same
Minnesota	Yes	Rural (4), Urban (2)	Kept the Same
Nevada	Yes	Unknown	---
New Jersey	Yes	48	Kept the Same
North Dakota	Yes	---	Kept the Same
Oregon	Yes	---	Kept the Same
Arkansas	Yes	24	Kept the Same
Colorado	Yes	48	Kept the Same
North Carolina	Yes	24	---
Washington	Yes	Varies	---
Virginia	Yes	24	Kept the Same
Tennessee	Yes	48	Conducting Study

3.4. Traffic Incidents Related Laws Changed Recently?

Another question asked was whether the law changed recently to facilitate dealing with highway incidents. If yes, why did the law changed with choice options being; 1) to reduce secondary crashes, 2) to reduce congestion, 3) to keep shoulders clear for emergency response units and for any other reasons. Table 5 shows 56% of the states surveyed had the law changed recently due to the impact of highway incidents. The central factor cited to influence recent law changes was to reduce secondary crashes.

Table 5
Law Changed and Benefits of the Law

State	Law Changed	Year Changed	Reasons for Changes
Kansas	Yes	2009	Reduce Secondary Crashes, Congestion, clear shoulder and others
Minnesota	Yes	2009	Reduce Secondary Crashes & Congestion
Nevada	Yes	2011	Reduce Secondary Crashes & Keep Shoulder Clear
New Jersey	Yes	Unknown	Move Over Law
North Dakota	No	NA	NA
Oregon	No	NA	NA
Arkansas	No	NA	NA
Colorado	No	NA	NA
North Carolina	Yes	Last few years	Reduce Secondary Crashes, Congestion clear shoulder
Washington	No	NA	NA
Virginia	No	NA	NA
Tennessee	No	NA	NA

3.5. Average Incident Duration

The survey also asked the average incident duration for each of the state surveyed. Table 6 shows that the statewide average incident duration varies by states. The minimum average incident duration was 31 minutes (Minnesota) and the maximum was 792 minutes in Oregon but for incidents involving hazardous materials. The average incident duration for the state of Tennessee is 57 minutes which is less than that of Oregon and North Carolina but higher than Minnesota and New Jersey.

Table 6
Average Incident Duration

State	Average Duration
Kansas	No data
Minnesota	31 min
Nevada	Unknown
New Jersey	45 min
North Dakota	---
Oregon	Hazardous (792 min) non-hazardous (112 min)
Arkansas	---
Colorado	---
North Carolina	60 min
Tennessee	57 min

4. Statistical tests on incident durations

Statistical tests were utilized to draw conclusions on the impact of different factors related to abandoned and disabled vehicle incident durations. Tests provided mechanism for making quantitative decisions about these types of incidents. The following two statistical tests were applied:

1. One-Sample t-test which compared the mean incident durations. The set standard for this study was 30 minutes and 60 minutes incident durations. The one sample t-test is given by the following formula.

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}$$

Where \bar{x} is the mean, μ_0 is mean value to be tested, s is the standard deviation, and N is the size of the sample.

2. Two sample t-test was used to compare the abandoned and disabled vehicles incident duration with respect to 1) queuing formation, 2) towing involvement and 3) shoulder involvement. The test helped to answer questions regarding whether or not the average incident duration was the same if the incident involved towing or not, if the incident involved queue backup or not and if the vehicle was parked at the shoulders or not. Two-sample t-test is based on the following formulation:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_1^2/n_1 + s_2^2/n_2}}$$

Where \bar{x}_1 and \bar{x}_2 are the means of the two samples, s_1 and s_2 are the standard deviations of the two samples, and n_1 and n_2 are the sizes of the two samples.

4.1. Test for mean incident duration

Considering the incident duration distribution, most of the incidents were cleared within 30 minutes. As the average incident duration was found to be 57 minutes, one-sample t-test was applied to determine whether the mean incident duration was statistically different from 30 minutes or 60 minutes. The test results shown in Table 7 indicate that the mean of incident duration was significantly higher than 30 minutes but not significantly different from 60 minutes.

4.2. Test for mean queue length

The analysis showed 80% of the incidents did not cause queue backup, 11% caused queuing of up to one mile and 9% caused two or more miles of queue backup. The statistical test was performed to determine if the mean queue length formed was statistically different from 0.5 miles or 1 mile. With significance level of 99.84% the results in Table 7 indicate that the mean of queue length of 0.71 was significantly higher than 0.5 miles but also significantly lower than 1.0 miles. The mean durations for incidents that resulted in queue back-up and those resulted with no queuing are about 63 and 55 minutes respectively. The test evaluated whether the difference between the two mean durations (8 minutes) was statistically significant. The results are presented in Table 8 showing the difference is significantly lower or higher statistically.

4.3. Test for mean duration before towing

The test determined whether the mean duration before towing was statistically different from 30 minutes or 60 minutes. Results in Table 7 shows the mean of incident duration before towing of 61 minutes was significantly higher than 30 minutes but not significantly different from 60 minutes. The difference between the incident durations for incidents involving towing (53.5 minutes) and those towing was not involved (57.7 minutes) was also tested. The difference of 6 minutes was found not statistically significant as shown in Table 8.

4.4. Incident duration differences based on shoulder involvement

The average incident duration for incidents that involved shoulder was 51.2 minutes and for those in which shoulder was not involved, the average duration was 73.3 minutes. The difference between the two durations is 22.1 minutes. The test therefore evaluated if this 22.1 minutes difference was statistically significant. As shown in Table 8, the difference is about 89% significant.

Table 7
Summary of one-sample t-tests

Test type	H ₀ (Null hypothesis)	H _a (Alt. hypothesis)	Actual Mean	Significance level	Statistically significant
Mean Incident Duration test (minutes)	Mean=30	H _a : mean<30	56.58	Pr(T<t)= 0.9997	No
		H _a : mean>30		Pr(T>t)= 0.0003	Yes
	Mean=60	H _a : mean<60	56.58	Pr(T<t)= 0.3289	No
		H _a : mean>60		Pr(T>t)= 0.6711	No
Mean Queue Length test (miles)	Mean=0.5	H _a : mean<0.5	.71	Pr(T<t)=0.9844	No
		H _a : mean>0.5		Pr(T>t)=0.0156	Yes
	Mean = 1	H _a : mean<1.0	.71	Pr(T<t)=0.0016	Yes
		H _a : mean>1.0		Pr(T>t)=0.9984	No
Mean Duration before Towing test (minutes)	Mean =60	H _a : mean<60	61.27	Pr(T<t)=0.5329	No
		H _a : mean>60		Pr(T>t)=0.4671	No
	Mean =30	H _a : mean<30	61.27	Pr(T<t)= 0.9778	No
		H _a : mean>30		Pr(T>t)=0.0222	Yes

Table 8
Summary of Two-Sample t-Tests

Response to be compared	Comparable data	Actual Mean	H ₀ (Null hypothesis)	H _a (Alt. hypothesis)	Significant level	Statistically significant
Incident Duration (minutes)	No Queue	55	diff= 0	diff < 0	Pr(T<t)=0.3434	No
	Queue Formed	62.7		diff > 0	Pr(T>t)=0.6566	No
	No towing	57.7	diff= 0	diff < 0	Pr(T<t)=0.5946	No
	Towed	53.5		diff > 0	Pr(T>t)=0.4054	No
	No Shoulder Involved	73.3	diff= 0	diff < 0	Pr(T<t)=0.8896	No
	Shoulder Involved	51.2	diff > 0	Pr(T>t)=0.1104	Yes	

5. Conclusion and Recommendations

The literature review and the questionnaire survey findings showed the abandoned and disabled vehicle incidents are problematic in other states as it is in Tennessee. The existing laws governing removal or relocating disabled and abandoned in other states are almost the same or worse compared to that of Tennessee. It was found that most states are satisfied with their current laws regarding abandoned and disabled vehicles. There have been law changes in some states to facilitate incident management. The towing of abandoned and disabled vehicles in many states ranges from 24-48 hours after the incident. Furthermore, very few states have conducted research studies specifically directed to disabled and abandoned vehicle incidents. The average incident durations in many states ranges from 30-60 minutes while that of Tennessee is 57, well within the range. In addition, most states use private towing companies to remove abandoned and disabled vehicles the same as Tennessee. The mean of incident duration in Tennessee is significantly higher than 30 minutes while the mean queue length is significantly higher than 0.5 miles and significantly less than 1.0 mile. There is no statistically significant difference between the mean of incident duration for incidents resulting with or without queuing. The mean of incident duration for incidents on sections with no shoulder is significantly higher than those on section with shoulders. Based on the findings, the study concluded that the 48 hours time limit requirement by Tennessee Code Annotated for removal of abandoned

and disabled vehicles has no significant negative effect on the traffic safety and operations. Therefore there is no need to change the code which was the goal of study evaluation.

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