AN ANALYTICAL REVIEW OF STATEWIDE ROUNDABOUT PROGRAMS AND POLICIES

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AN ANALYTICAL REVIEW OF STATEWIDE ROUNDABOUT PROGRAMS AND POLICIES

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LIST OF SYMBOLS AND ABBREVIATIONS

DOT	Department of Transportation
NCHRP	National Cooperative Highway Research Program
SHA	Maryland State Highway Administration
ADA	American with Disabilities Act
Access Board	United States Access Board
ITRE	Institute for Transportation Research and Education
WisDOT	Wisconsin Department of Transportation
KDOT	Kansas Department of Transportation
NYSDOT	New York State Department of Transportation
VMT	Vehicle Miles of Travel
KAI	Kittelson & Associates, Inc.
MUTCD	Manual of Uniform Traffic Control Devices
HCM	Highway Capacity Manual

SUMMARY

As the modern roundabout continues to grow in popularity within the United States, more states are considering or implementing statewide roundabout programs and policies. The growth in the number of roundabouts in the United States is largely due to the safety and operations benefits associated with the use of roundabouts.

To assist states with the implementation of statewide roundabout programs and policies, an analytical review of statewide roundabout programs and policies was conducted through an examination of literature, interviews, and data pertaining to the construction of roundabouts.

The roundabout policy type for each state and the District of Columbia was located, and assigned to a roundabout policy type based on the strength of the identified policy type. In addition, a series of per capita analyses of the statewide roundabout policies was performed, as was a qualitative SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis.

The results of the analysis show that the strength of a statewide roundabout policy is correlated to the number of roundabouts in a state, and states should consider implementing or strengthening their policies if they seek to expand the use of roundabouts in their jurisdiction. In addition, the perception of roundabouts, both by the general public and internal to the state DOTs, also continues to hinder the further implementation of roundabouts, and education should be utilized to minimize these obstacles. Furthermore, states should utilize identified successful implementation procedures, and should be cognizant of reasons for implementation failure, as they pursue the further use of roundabouts by their agency.

CHAPTER 1

INTRODUCTION

1.1 Study Overview

With approximately 2,000 roundabouts currently in operation in the United States and Canada, and close to two decades of experience, the modern roundabout has become an important strategy for improving the performance of the transportation system in North America (1). However, the implementation of roundabouts in the United States has not occurred at anywhere near the same degree as found internationally.

While the first one-way traffic circle was built in the United States at New York City's Columbus Circle in 1905, traffic circles in the United States fell out of favor in the 1950s due to serious operational and safety problems. In the 1950s, the United Kingdom began experimenting with "off-side priority" in which entering vehicles would yield to circulating vehicles. Research by the Road Research Laboratory (now the Transport Research Laboratory) showed increases in capacity, reductions in delay, and a decrease in injury accidents due to the implementation of off-side priority (2). Consequently, off-side priority (yield on entry) was officially adopted for roundabouts in the United Kingdom in 1966, and the modern roundabout was created.

Even though roundabouts had been successfully implemented worldwide since their introduction in the United Kingdom, it was not until the late 1980s, with roundabouts in Colorado and Nevada, that they were introduced to the United States (2) (3) (4). Since then, due in large part to the establishment of roundabout policies and programs by state and local government that have defined the specific contexts within which roundabout designs are appropriate, the construction of roundabouts in the United

States has increased dramatically (see Figure 1), with many more roundabout designs currently underway (5).

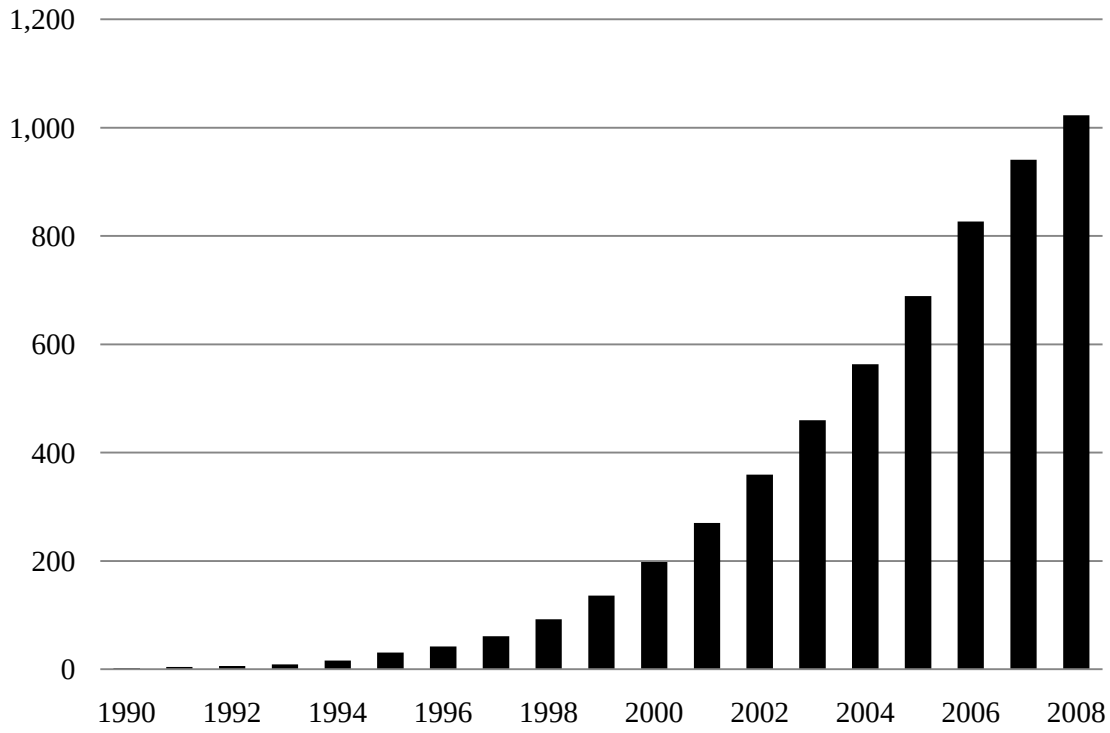

Figure 1. Cumulative number of roundabouts in the United States by year constructed (6)

The purpose of this research is to assess the status of statewide roundabout programs and policies in the United States in an attempt to identify the current state of the practice for roundabout policies and programs. This information helps identify the strengths, weaknesses, opportunities and threats associated with current statewide policies and programs. The research specifically examines successful roundabout implementation strategies.

Chapter 2 summarizes the literature on roundabout policies and programs, and briefly touches on organizational change and implementation procedures. Chapter 3 presents a summary of current statewide roundabout policies; Chapter 4 presents the data

collection methodology, Chapter 5 presents the methodology utilized; and Chapter 6 presents the analysis and results of this research. Chapter 7 provides conclusions and recommendations.

CHAPTER 2

LITERATURE REVIEW

In order to provide a context and basic understanding of roundabouts, the literature summarized in this chapter provides a concise history of roundabouts in the United States, the reasons for the growth in the number of roundabouts, and the development of roundabout policies and programs. Furthermore, this chapter synthesizes available research on roundabout policies and programs, and provides a brief examination of organizational change and implementation research in the context of the transportation system.

For purposes of this thesis, the following definitions are used:

- **Statewide Roundabout Program** A statewide initiative overseen by personnel within the state's department of transportation dedicated to the planning, engineering and design, construction and maintenance, public outreach and education, and research of roundabouts in the state (7).
- **Statewide Roundabout Policy** A deliberate and enforceable statewide plan of action to guide decisions pertaining to the construction of roundabouts in the state.
- The terms **roundabout** and **modern roundabout** are used interchangeably.

2.1 Introduction to the Modern Roundabout

The modern roundabout is essentially an "engineered" traffic circle that has been designed for safe and efficient operation. It is defined by three distinguishing characteristics (8):

1. They are generally circular in shape,
2. They have geometric features to slow traffic passing through the intersection, and
3. They are always yield controlled for the motorist entering the roundabout.

2.1.1 Roundabout Growth in the United States

As displayed in Figure 2, the cumulative number of roundabouts has increased dramatically since their introduction to the United States. It is estimated that as of April 2010, over 2,000 roundabouts have been built in the United States. (9) However, roundabouts have not been built uniformly across the United States. As displayed in Figure 2, which shows the growth of roundabouts per state in the United States since 1990, several states stand out as leaders in the construction of roundabouts, including: Washington, California, Colorado, Florida, North Carolina, Virginia, and Maryland. Each of these states had more than 50 roundabouts as of 2007, according to a database maintained by Kittelson & Associates, Inc. (10)

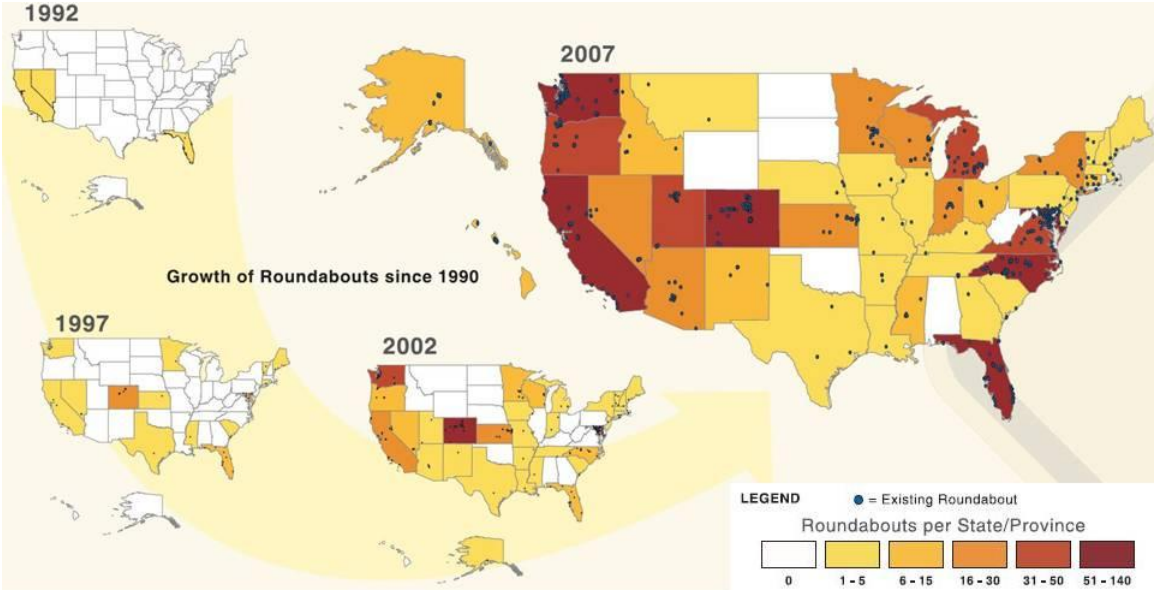

Figure 2. Growth of roundabouts per state since 1990 (11).

In general, the states with the highest number of roundabouts were also early adopters of roundabouts. However, several notable exceptions include Virginia and North Carolina. Virginia is particularly notable because in 2002 the Commonwealth had no roundabouts in the database, whereas by 2007, over 50 roundabouts had been constructed. This is in direct contrast to Nevada where a roundabout was first built in 1990, and by 2007, the state had fewer than 15 roundabouts.

2.2 Roundabout Benefits

Compared to other intersection types, roundabouts often provide improved safety and operational benefits. A brief discussion on these benefits is provided below.

2.2.1 Safety

In 2007, the National Cooperative Highway Research Program (NCHRP) Report 572: *Roundabouts in the United States* (8) confirmed earlier findings that showed reduced crash rates at intersections converted to roundabouts (12). In general, this report found that, "roundabouts have improved both overall crash rates and, particularly, injury crash rates in a wide range of settings (urban, suburban, and rural) for all previous forms of traffic control except for all-way stop control, for which no statistically significant difference could be found" (8). Table 1 displays the change in crash rates after the conversion to a roundabout as presented in NCHRP 572.

Table 1. Change in crash rates after conversion to a roundabout (8)

Intersection Type	Change in Total Crashes After Conversion	Change in Severe Injury Crashes After Conversion
All Four-Way Intersection	-35%	-76%
Signalized Urban	Too Few	-60%
Signalized Suburban	-67%	Too Few
All-Way Stop Controlled	Similar	Similar
Two-Way Stop Controlled Urban	-72%	-87%
Two-Way Stop Controlled Suburban	-32%	-71%
Two-Way Stop Controlled Rural	-29%	-81%

As an example of how one state considers the safety aspects of roundabouts, the Maryland State Highway Administration (SHA) has used expected safety benefits to justify many of the initial roundabouts constructed in the state (13). A 2006 SHA report on 19 single-lane roundabouts that have been in service for three to five years reported a 68% decrease in the total crash rate, a 100% decrease in the fatal crash rate, an 86% reduction in the injury crash rate, and a 40% reduction in the property-damage-only crash rate at these locations (14). Additionally, a benefit/cost analysis revealed that safety benefits resulted in an approximate $13.00 return for every dollar spent on roundabouts.

2.2.2 Operations

A roundabout typically experiences significantly less delay than a signalized intersection having comparable traffic volumes. As shown in Figure 3, at signal warrant volume thresholds found in the *Manual of Uniform Traffic Control Devices (MUTCD)*, a vehicle at a roundabout experiences approximately 12 seconds less delay as compared to at a traffic signal with similar turning volumes (8). In addition, drivers in the United States appear to use roundabouts less efficiently than in other countries, making it likely

that as drivers in the United States become more familiar with roundabouts, operations will continue to improve (8).

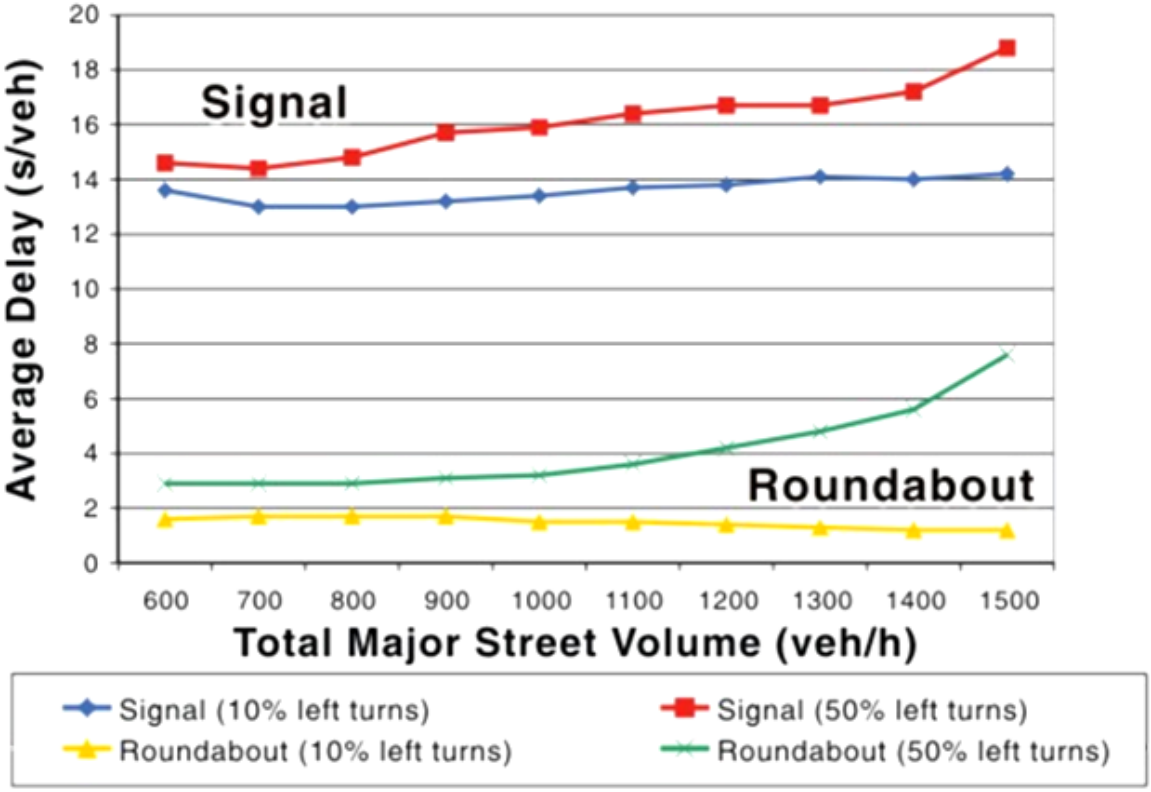

Figure 3. MUTCD signal warrant volume threshold (8) (Based on MUTCD 2000 edition, Warrant 3).

2.2.3 Issues with Roundabouts

2.2.3.1 General Acceptance

Although the safety and operational benefits of roundabouts are well documented, some states have been slow to build roundabouts. The "principal impediment [to the construction of roundabouts] is the negative perception held by some drivers and elected officials" (9) which has been termed "roundabout anxiety." (15) As has been demonstrated on countless occasions, the public will usually have a negative opinion of roundabouts prior to the installation of the first roundabout in a jurisdiction not having

roundabouts. (16) However, as displayed in Figure 4, after construction of a roundabout, the public attitude towards roundabouts tends to shift from negative to positive.

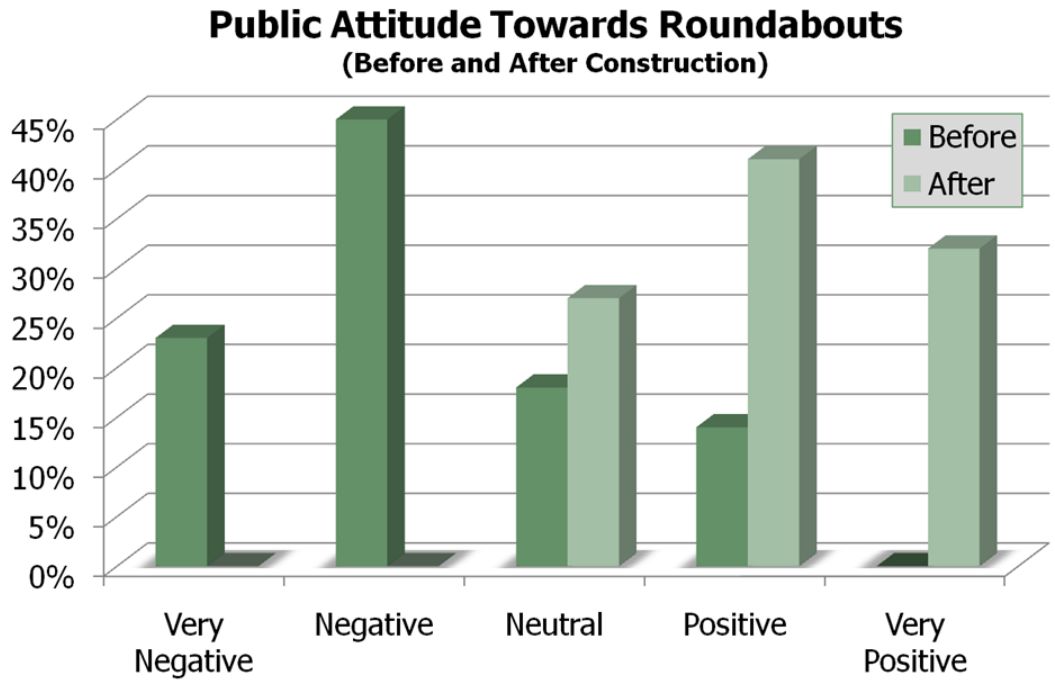

Figure 4. Public attitude towards roundabouts (before and after construction) (16)

2.2.3.2 Suitability

Similar to other intersection types, roundabouts are not suitable in a number of locations. According to the *Kansas Roundabout Guide*, extra caution should be exercised when considering roundabouts at the following types of locations (17):

- Intersections in close proximity to a signalized intersection where queues may spill back into the roundabout.
- Intersections located within a coordinated arterial signal system.
- Intersections with a heavy flow of through traffic on the major street opposed by relatively light traffic on the minor street.
- Intersections with physical or geometric complications.

- Locations with steep grades and unfavorable topography that may limit visibility and complicate construction.
- Intersections with heavy bicycle volumes.
- Intersections with heavy pedestrian volumes.

As stated in the *Kansas Roundabout Guide*, other traffic control devices would also be problematic at many of the locations listed above.

2.2.3.3 Cost

In addition, cost considerations also play a role in impeding the growth of roundabout construction. In general, roundabouts tend to cost more than a signal or stop controlled alternative. Consequently, it can be difficult to convince public agencies to implement roundabouts when another alternative is capable of operating effectively as well. Most jurisdictions now complete a life-cycle cost analysis for the roundabout and the other alternatives instead of simply comparing the capital costs. When the safety benefits of a roundabout are included in the analysis, a roundabout tends to become a more attractive alternative. Additionally, in certain locations where bridge widening or other road widening would have been necessary under a signalized alternative, roundabouts have proven to be a much cheaper alternative (7).

2.2.3.4 Visually-Impaired Pedestrians

Concerns have been raised about the accessibility of roundabouts to persons with severe visual impairments (18). In particular, the United States Access Board (Access Board) has found that pedestrian crossings at multilane roundabout entries and exits are not accessible to people with disabilities (19) as required under Title II of the American with Disabilities Act (ADA), and other statutes (20). This is because visually-impaired

pedestrians have to rely on auditory cues to make crossing decisions at intersections. With free-flow exit lanes, and yield-controlled entry lanes, plus the ambient noise and uninterrupted flow in the nearby circulatory roadway, it can be difficult for visually impaired pedestrians to detect appropriate crossable gaps (21).

A literature review (21) by Dr. Schroeder at the Institute for Transportation Research and Education at North Carolina State University (ITRE) revealed that roundabout facilities pose serious crossing difficulties (22), and that crossing becomes increasingly difficult as the conflicting vehicular volume increases (23). Moreover, roundabout exit legs are more problematic for pedestrians than entry legs (24).

Consequently, the Access Board has proposed to require "pedestrian activated signals (including accessible pedestrian signal features)…for each segment of the crosswalk, including the splitter island" at all multilane roundabouts with provided pedestrian facilities (25). Single-lane roundabouts are exempt from the pedestrian-signal requirement because the Access Board found that roundabouts with single-lane crossings can provide cues that make non-visual use possible.

Furthermore, the Access Board has provided guidance regarding the type of pedestrian-crossing signals recommended at roundabout pedestrian crossings (25):

> *Advisory R305.6.2 Signals. There are many suitable demand signals for this application. Crossings at some roundabout intersections in Australia and the United Kingdom incorporate such systems, in which the driver first sees a flashing amber signal upon pedestrian activation and then a solid red while the pedestrian crosses to the splitter island (there is no*

green). These types of signals are also used in some U.S. cities at pedestrian crossings of arterial street or highways…

Concerns have also been raised about the cost of pedestrian signals (26), and increased delays to vehicular traffic at the roundabout (21). Furthermore, the potential for queue spillback into the circulatory roadway due to the signalization of the exit leg has been raised as an issue as well (19).

This proposed rule change, if implemented, has the potential to have a large impact on the number of multilane roundabouts constructed in the United States. In general, roundabouts tend to have a higher initial cost compared to other intersection alternatives (4). Accordingly, the requirement for pedestrian signals at all multilane roundabout crossings has the potential to cause a proposed roundabout to be deemed too costly (26). It is also possible that roundabouts will be built without pedestrian facilities or as a single-lane roundabout with a shorter design life to satisfy the proposed rule.

2.3 Programs

This subsection briefly provides a case study review of four statewide roundabout programs, and describes the general themes and lessons learned from these four states. The four states--Kansas, Maryland, New York and Wisconsin--were selected for a more detailed assessment of the factors that contributed to the successful implementation of roundabouts in the state. The states were selected based on the number of roundabouts successfully implemented as well as professional judgment that these states were considered by their peers as national leaders.

2.3.1 State's Introduction to Roundabouts

The manner in which each state was introduced to roundabouts varies. For instance, the Wisconsin Department of Transportation (WisDOT) was introduced to roundabouts by WisDOT employees with roundabout experience from other state DOTs. The Kansas Department of Transportation (KDOT) and New York State Department of Transportation (NYSDOT) were introduced to roundabouts at technical conferences. Maryland's SHA was introduced to roundabouts in the 1980s by a vocal advocate for such treatments.

Each jurisdiction is similar in that a "champion" or "champions" took the lead in promoting roundabouts during the early stages of the roundabout program. In Kansas, the state traffic engineer was introduced to roundabouts at a conference, and became the roundabout champion at KDOT. In Maryland, a concerned citizen played this role, and gained the attention of the state traffic engineer and the state planning director through one of the state's U.S. Senators. Given that Maryland was the first state to adopt a statewide roundabout program, it is instructive to learn more about the early stages of acceptance within SHA.

Maryland adopted a statewide roundabout program after SHA determined a roundabout was the preferred alternative on an interchange project (27). However, a Maryland Roundabout Task Force decided that a smaller single-lane roundabout would be more suitable for the first roundabout in the state, and consequently a location with a significant number of crashes – many severe – was identified. Due to a considerable amount of community opposition and pressure, SHA agreed to install a temporary roundabout, and vowed to remove it during the first six months if either the community

did not adjust to the new form of intersection control, or it was not performing as SHA officials anticipated. After three months, community members requested that SHA make the roundabout permanent citing a considerable reduction in delay, and more importantly, the perception of improved safety benefits (4).

SHA has since adopted a policy stating that roundabouts will be considered at all intersections where improvements are being considered. This policy has led to one of the largest number of roundabouts constructed on a state system in the country. Most of the first roundabouts constructed by SHA were at low to medium-volume sites with a high crash record. All of these initial roundabouts are still in place today and have experienced a very low crash rate. SHA has since constructed roundabouts in a variety of settings ranging from locations with low volume to high volume, and in rural, suburban and urban settings (4).

2.3.2 Number and Location of Roundabouts

Table 2 displays the number of single-lane, double-lane, and triple-lane roundabouts constructed and maintained by each of the states in this study. State DOT representatives from each state said that they would like to see the number of roundabouts constructed per year increase. However, KDOT and Maryland SHA officials projected the rate of roundabouts constructed per year to decrease in the near future due to funding constraints and the pending Access Board decision on pedestrian treatments at multi-lane roundabouts.

Table 2. Number of single-lane, double-lane, and triple-lane roundabouts constructed and maintained by jurisdiction as of May 2008

	Constructed	Maintained	Single-Lane[1]	Double-Lane[2]	Triple-Lane[3]
Kansas	9	3	6	3	1*
Maryland	65	65	43	22	2**
New York	44	32	26	18	0
Wisconsin	30	0	5	25	1*

1. Indicates single-lane entry on all approaches and one circulating lane in roundabout
2. Indicates double-lane entry on at least one approach, and two circulating lanes conflicting with at least one approach
3. Indicates triple-lane entry on at least one approach, and three circulating lanes conflicting with at least one approach
* Under construction
** Two double-lane roundabouts are being converted to triple-lane roundabouts

As seen in Table 2, the number of roundabouts constructed and maintained by each jurisdiction varies, as does the proportion of single-lane roundabouts to multi-lane roundabouts. Furthermore, even in these established roundabout programs, there are still relatively few triple-lane roundabouts. Of the jurisdictions interviewed, Maryland has the oldest roundabout program (1993), and consequently has the most roundabouts (65) of the programs reviewed.

As seen previously in Figure 1, the number of roundabouts constructed in the United States has grown dramatically; however, the rate of new roundabouts constructed per year is still relatively small. In the establishment of its roundabout program, Maryland put special emphasis on ensuring that the first roundabout constructed and maintained by the state would be successful. Fifteen years after the construction of the first state highway system roundabout, Maryland constructs four to five roundabouts per year on average, with the largest number being ten roundabouts constructed in 2002 (4).

As seen in Table 3, roundabouts have been constructed in a variety of land use contexts. From an urban setting like the Towson roundabout in Maryland, to a high-speed

rural roundabout in Kansas with 65 mph approaches, roundabouts have been able to operate with acceptable performance.

Table 3. Number of single-lane, double-lane, and triple-lane roundabouts constructed and maintained by jurisdiction as of May 2008

	Urban	Suburban	Rural	High Speed Rural[1]
Kansas	5	1	3	3
Maryland	5	34	26	5*
New York	10	20	6	2
Wisconsin	-	Most	-	2

1. The high-speed designation was interpreted differently by each jurisdiction and therefore may not be consistent
* Approximately

2.3.3 Feasibility Studies, and Design Reviews

While the exact process varies between jurisdictions, the basic process for evaluating the feasibility of roundabouts is similar for each. The typical steps for conducting a feasibility analysis are outlined below, and are similar to feasibility studies that are conducted for any intersection type:

- Any obvious fatal flaws are identified (inadequate right-of-way, cost prohibitive, inadequate grade, imbalanced traffic flows, etc…)
- Criteria for evaluating the roundabout are determined (traffic operations, safety, cost, etc…).
- Any constraints to the roundabout are identified (design vehicle, land use, grade, right-of-way, driver expectancy, local knowledge of roundabouts, etc…)
- A comparison to other alternatives is completed. Most jurisdictions also complete a life-cycle cost analysis for the roundabout and the other alternatives instead of simply comparing the capital costs.

Figure 5 displays a flow chart of the evaluation and design process for roundabouts from the Indiana Department of Transportation

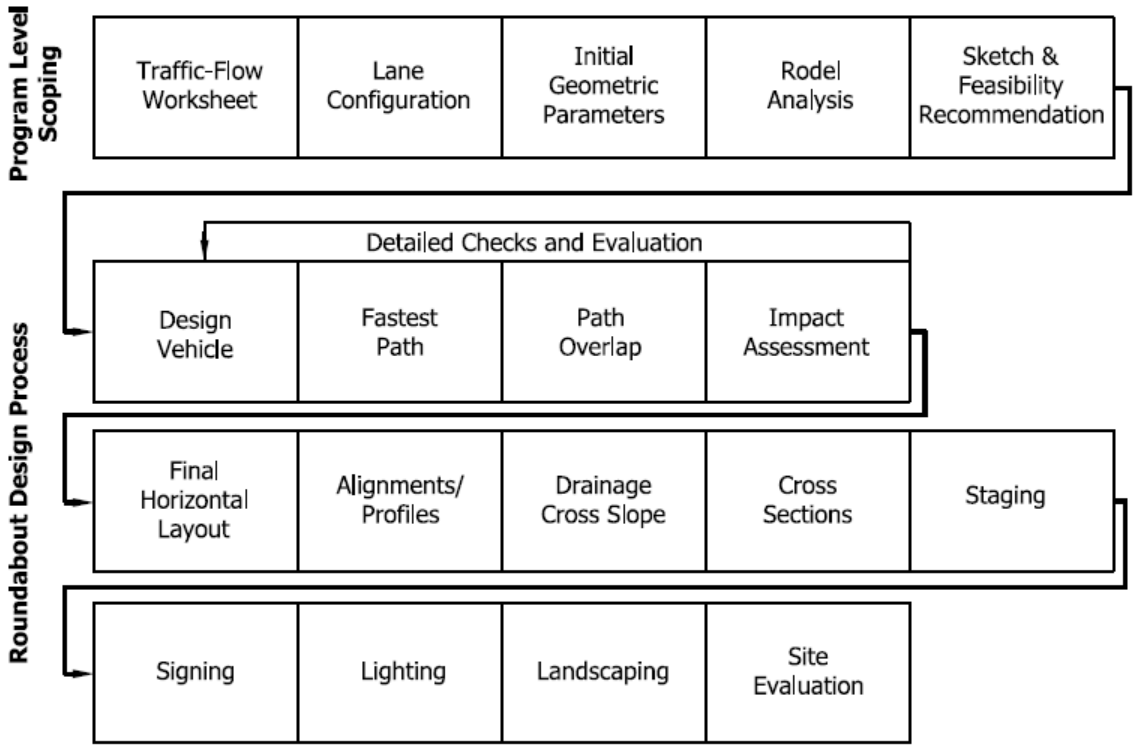

Figure 5. Evaluation and design process (28)

In addition, each of the four states has a design review process to ensure the quality and consistency in design throughout the jurisdiction. However, the process for the design reviews varies among jurisdictions. New York reviews every roundabout in-house at the central office; Kansas and Wisconsin either review the roundabout in-house, or use outside consultants; and Maryland uses only outside consultants to conduct the review. While the manner in which designs might be reviewed varies among the jurisdictions, the fact that a central authority oversees the review of every roundabout does not.

Kansas takes the design review a step further, by offering design reviews for local jurisdictions at no charge in order to ensure consistency in design throughout the state.

This ensures that whether a roundabout is constructed by the state or a local community, the basic design principles will remain the same. Perhaps more importantly, this ensures that a local jurisdiction will not build a substandard roundabout that has the potential to set back the roundabout program in that area.

2.3.4 Driver Education, Public Acceptance, and Education

Educating drivers on how to navigate a roundabout was a priority for each of the four states. Each jurisdiction has developed a brochure or handout related to roundabouts, and each state has materials relating to roundabouts available for public meetings. Public reluctance of roundabouts has largely been overcome in Maryland, whereas in Kansas, public acceptance is still a major part of the project development process. This is likely related to the number of roundabouts constructed by SHA in Maryland (65), versus the number of roundabouts constructed by KDOT (9) in Kansas. Some innovative public education programs included:

- Videos that have been developed and made available to the public, and/or placed on websites;
- Animations of vehicles, pedestrians, and bicycles traversing a roundabout on websites;
- Displaying videos on televisions at on local cable access stations and/or at local stores or malls;
- Placing brochures in grocery bags at local stores;
- Working in collaboration with local organizations (AARP, Motor Carrier groups, Senior Driver groups, etc…); and

- Driver educations programs, presentations and interactive demonstrations to elementary, middle-school, and high-school students.

Public perception and reluctance to roundabouts is the biggest hurdle a roundabout program must overcome. It is far simpler to construct a roundabout in a location where there is a public perception of a problem. As was seen in Maryland, it makes strategic sense from a programmatic perspective to ensure that the first few roundabouts constructed are successful, and are accompanied with intensive public meetings and public education.

2.3.4.1 Traffic Circles vs. Roundabouts

Part of the public acceptance issue is the lack of proper public awareness of the difference between roundabouts and traffic circles. While all roundabouts are traffic circles, not all traffic circles are roundabouts. In some areas, a large amount of traffic calming circles have been built that are an annoyance to most drivers, and consequently drivers are against roundabouts on streets with a functional classification above local streets. Additionally, in the northeastern United States, many rotaries are in the process of being removed due to their poor safety and operational history. Rotaries in the northeast have hampered the development of roundabouts in this area due to the perception that traffic circles are not safe and do not operate effectively.

2.3.4.2 Internal Education and Training

In jurisdictions that have a limited number of roundabouts, educating agency staff has been a challenge. Education is not only an issue for the public, but for the agency staff implementing roundabouts as well. It is important that enough expertise be available

within the agency to have an understanding of roundabouts, and be able to review roundabout designs and operational analyses.

2.3.5 Maintenance Issues

The most common maintenance issue identified in the four states was trucks failing to use the provided truck apron. Both New York and Wisconsin use colored concrete stamped to look like bricks for truck aprons, and both states found that trucks were not using the apron because the trucks did not want to ruin what looked like decorative brick. New York solved this problem by driving vehicles on the truck apron prior to opening the roundabout in order to place skid marks to show trucks it was acceptable to use the truck apron, and Wisconsin largely solved the problem through education efforts and signs encouraging trucks to use the truck apron. However, in rural locations where overweight loads are common, concerns have been raised that off-tracking through the roundabout on the truck-apron will cause the truck to tip. There have been no reported incidents of trucks tipping, but Kansas is closely monitoring this potential risk.

With regard to central-island landscaping, most jurisdictions reach agreements with local communities or garden clubs to maintain either the vegetation or artwork located on the central island. Where local agreements are not reached, low maintenance landscaping is commonly used.

Each state DOT official was asked about snow removal, and each replied that snow removal was not an issue. While each state handles snow removal differently (some push the snow to the central island, and some push the snow to the shoulder on the approach lanes) snow removal has not caused a roundabout to fail.

2.3.6 Pedestrian and Bicycle Accommodations

The states in the interview sample predominantly oversee roundabouts constructed in suburban locations, and therefore the majority of roundabouts see sporadic pedestrian and bicycle use. However, roundabouts have been constructed in each of the states where there is a heavy pedestrian volume. Where pedestrians are expected, each of the states provided basic pedestrian amenities to include sidewalks, marked pedestrian crossing, and curb cuts on the splitter island and on the outside curb for the entering and exiting approaches.

ADVANTAGES	DISADVANTAGES
Vehicle speed is reduced, compared to that for another intersection type.	Vehicle traffic is yield controlled, so it does not necessarily come to a full stop. Therefore, a pedestrian can be hesitant at first to use the crosswalk.
A pedestrian has fewer conflict points that at another intersection type.	A roundabout can be unsettling to a pedestrian, depending on age, mobility, visual impairment, or ability to judge gaps in traffic.
A pedestrian is responsible for judging crossing opportunity. This is still regarded as an advantage, though it requires more alertness.	A pedestrian, at first glance, can have to adjust to roundabout operation. This includes the crosswalk location, which is behind the first stopped vehicle, or 6 m from the yield point.
The splitter-island refuge allows a pedestrian to cross entering and exiting traffic flows separately, and thus simplifies the task of crossing the roadway.	
Crossing can be accomplished with less waiting time than at a signalized intersection.	

Figure 6. Roundabout advantages and disadvantages for pedestrians (28)

At roundabouts, bicyclists have the option of circulating through the roundabout as a vehicle or as a pedestrian, if pedestrian amenities have been provided. None of the state DOTs provide bike lanes through the roundabout. Some jurisdictions provide bike ramps so that bikes on bike lanes approaching the roundabout can easily enter a mixed-use path to circumnavigate the roundabout as a pedestrian. The low speed nature of the

roundabout however, makes it convenient for bicyclists to circulate through a roundabout as a vehicle, if desired.

All four states also cited concern with the previously mentioned proposed Access Board rule requiring signals at all multi-lane roundabouts with provided pedestrian amenities. In anticipation of the proposed Access Board ruling, several states have begun to place conduits at multi-lane roundabouts during construction to accommodate a signal in the future. Further, while several states also push the zig-zag crossing as a standard pedestrian crossing design at roundabouts, they remain somewhat skeptical that pedestrians will obey the crossing due to the additional out-of-way travel required.

2.4 Policies

Depending on the jurisdiction, the policy outlining the feasibility of a roundabout varies. Maryland, New York, and Wisconsin each have state policies that require the analysis of roundabouts at all intersection projects where state or federal funding will be used. New York and Wisconsin policies also require that if the roundabout is found to be feasible, it becomes the preferred alternative. In New York, this policy was established based on the advice of NYSDOT's lawyers who found that NYSDOT could be liable for crashes that occurred at intersections where a roundabout was not considered as an alternative if a roundabout could be shown to have prevented the crash. While Kansas does not have a roundabout policy, "champions" within KDOT continue to encourage the analysis of roundabouts as an alternative.

2.5 Implementation

As previously described, there has been a dramatic growth in the number of roundabouts in the United States over the past two decades. Consequently, it can be

surmised that the debate over the general acceptability of roundabouts in the United States has been overcome with the roundabout asserting itself as a sustaining member of the national transportation system. However, the implementation of roundabouts is not ensured, and

In order to assess the potential for successful implementation, understanding why implementation has failed in some cases is informative. This section looks at sources of implementation failure and develops strategies for avoiding failure. Several sources of implementation failure exist, but perhaps the most common source is the implementation plan itself, as is commonly found, the "most troublesome issues plaguing organizational change initiatives are inherent in their design." (29) Further, Larson points out that poor implementation procedures are also a source of implementation failures. (30) Walter Williams, as quoted in the Larson paper (30), says:

> *The lack of concern for implementation is currently the crucial impediment to improving program operations, policy analysis, and experimentation in social policy.*

Further, Larson provides a survey of reasons for failure, reproduced in Table 4 below:

Table 4. Reasons for implementation failure (30)

Types	Hypothesized Relationship to Failure
Poor implementation procedures	Causes the least amount of failure. It can be remedied by altering the program, unless poor implementation is conscious or fraudulent.
Intergovernmental complexity	A moderate cause of failure. Remedy requires changing relationships among agencies and coordinating efforts.
Vague and unrealistic goals	A serious program flaw. It requires a complete restructuring of program direction.
Changes in the economic environment	A very serious source of program failure. Radical environmental change makes a program totally ineffective.

In addition, several strategies need to be utilized by state agencies in order to ensure successful implementation of roundabout programs and policies, and to minimize sources of implementation failure previously described. A review of literature that builds off the previously described successful implementation characteristics shows that the following are needed for successful project implementation (31):

1. The demonstration of a perceived need
2. Realistic expectations
3. Strong advocates
4. A defined and supportive constituency
5. A mix of implementation actions
6. Complementary programs
7. Analytical capability on the part of the implementation team
8. Abundant resources, including people and money

In addition, characteristics of successful project implementation often include the following: (31)

1. An individual or group of individuals who are committed to the project or program and able to overcome implementation obstacles
2. A flexible approach with respect to how implementation will occur
3. The development of a constituency that can the support the project
4. Consistent communication and feedback
5. A strong connection between professional goals and political power

Through an understanding of the above characteristics and a development of strategies to incorporate the characteristics into statewide roundabout policies, the successful implementation of roundabouts can occur.

CHAPTER 3

EXISTING STATEWIDE ROUNDABOUT POLICIES

A review of existing statewide policies was conducted to assess the status of roundabout policies in the United States. The review was conducted by examining information available online, and through interviews. For the purposes of the review, the type of policy was split into six categories, shown in Table 5.

Table 5. Types of roundabout policies

Category	Description
None	No policy or mention of roundabouts from the state DOT. Consequently, the state neither encourages nor discourages roundabouts.
Consider - Allow	The state allows the consideration of roundabouts
Consider - Encourage	The state encourages the consideration of roundabouts
Evaluate	The state requires the evaluation of a roundabout alternative
Justify	The state requires the evaluation of a roundabout, and written justification explaining when a roundabout is not the preferred alternative
Strong	The roundabout alternative is by default the preferred alternative, unless proven otherwise

Based on the categories displayed in Table 5, each state and the District of Columbia were assigned to a category. It should be noted that while the categorization of roundabout policy type was somewhat subjective (especially in the split between "Consider – Allow" and "Consider – Encourage"), the policy type categorization tended to be straightforward. For instance, the difference between "Consider – Encourage" and "Evaluate" was oftentimes as simple as the difference between "should" and "shall", respectively. An example of the policy text associated with each policy type category is given in Table 6, which lists example roundabout policy types from six states.

Table 6. Example roundabout policy types

State	Policy Type	Policy Text
Alabama	None	NA
Kentucky	Consider - Allow	A modern roundabout is an alternative form of intersection control to traffic signals and multi-way stop control intersections. Therefore, roundabouts may be considered only when these intersection control types are warranted.
Connecticut	Consider - Encourage	Those locations which meet or nearly meet [signal] warrants, should be given consideration for roundabout installation. Intersections that are, or proposed to be, all-way stop controlled may also be good candidate locations for a roundabout
Georgia	Evaluate	Roundabouts are the preferred safety and operational alternative for a wide range of intersections of public roads. A roundabout shall be considered as an alternative in the following instances: (1) Any intersection in a project that is being designed as new or is being reconstructed. (2) All existing intersections that have been identified as needing major safety or operational improvements. (3) All signal requests at intersections (provide justification in the Traffic Engineering Study if a roundabout is not selected).
Alaska	Justify	"Roundabout First" policy. Requires designers to provide a written justification of any decision to install a traffic signal instead of a single lane roundabout. (32)
New York	Strong	When the analysis shows that a roundabout is a feasible alternative, it should be considered the Department's preferred alternative due to the proven substantial safety benefits and other operational benefits.

Table 7 displays the results of this assignment, and the number of roundabouts constructed in the state. The appendix contains source information for the policy type and number of roundabouts, and the text of the policy, if available.

Table 7. Existing Statewide Roundabout Policies

State	Number	Policy Type
Alabama	1	None
Alaska	16	Justify
Arizona	115	Consider - Allow
Arkansas	4	Consider - Allow
California	126	Consider - Encourage
Colorado	240	Consider - Encourage
Connecticut	16	Consider - Encourage
Delaware	8	Consider - Encourage
District of Columbia	18	Consider - Encourage
Florida	99	Consider - Allow
Georgia	14	Evaluate
Hawaii	12	Consider - Encourage
Idaho	8	None
Illinois	3	Consider - Encourage
Indiana	150	Consider - Encourage
Iowa	34	Consider - Encourage
Kansas	86	Consider - Encourage
Kentucky	2	Consider - Allow
Louisiana	3	Consider - Allow
Maine	3	Consider - Allow
Maryland	160	Evaluate
Massachusetts	21	Consider - Encourage
Michigan	41	Consider - Encourage
Minnesota	80	Evaluate
Mississippi	14	None
Missouri	25	Consider - Allow
Montana	21	Consider - Encourage
Nebraska	5	Consider - Allow
Nevada	26	Consider - Encourage
New Hampshire	10	Evaluate
New Jersey	14	Consider - Allow
New Mexico	9	Consider - Allow
New York	32	Strong
North Carolina	81	Consider - Encourage
North Dakota	2	None
Ohio	27	Consider - Encourage
Oklahoma	1	None
Oregon	89	Consider - Encourage
Pennsylvania	3	Consider - Encourage
Rhode Island	4	Strong
South Carolina	3	None
South Dakota	1	None
Tennessee	7	Consider - Allow
Texas	16	Consider - Allow
Utah	160	Consider - Encourage
Vermont	7	Strong
Virginia	76	Justify
Washington	189	Evaluate
West Virginia	0	None
Wisconsin	116	Evaluate
Wyoming	3	None

As shown in Table 7, the type of policy varies between the states, with little correlation indicated between the number of roundabouts and the strength of a roundabout policy. Next, the number of states with each policy type was tabulated, and is displayed in Table 8.

Table 8. Summary of existing state roundabout policies

Policy Type	Number of States	Number of Roundabouts
None	9	33
Consider - Allow	12	302
Consider - Encourage	19	1,162
Evaluate	6	569
Justify	2	92
Strong	3	43
Total	**51**	**2,201**

As seen in Table 8, the most prevalent policy types were “Consider – Allow” and “Consider – Encourage” with 12 and 19 states, respectively. Currently, only 11 states formally require the analysis of a roundabout alternative as denoted by the “Evaluate”, “Justify” and “Strong” policy type categories. The remaining nine states have no formal or informal roundabout policy. The policy type categories were mapped in order to denote regional roundabout policy type trends. Figure 7 displays the roundabout policy type by state.

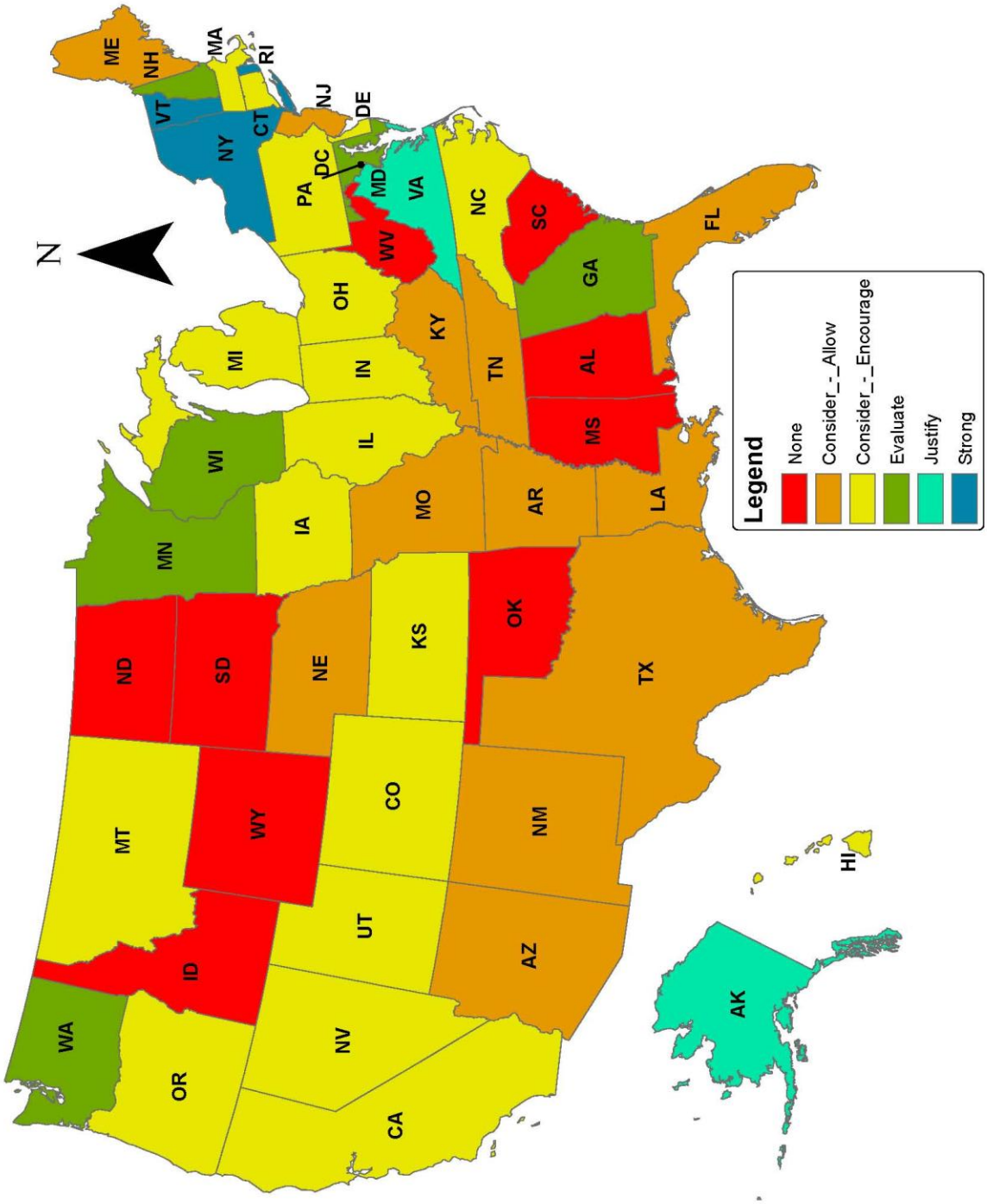

Figure 7. Roundabout policy type by state

Several loose trends emerge from a review of Figure 7. The states without a roundabout policy – denoted in red – are somewhat concentrated in the Southeastern part of the United States, and the northern parts of the Midwest and mountain west.

States with a policy type of "Consider – Allow" – as denoted in orange – are dispersed, yet connected, through several regions, including: the south mountain west, the western part of the Southeast, and the east-central portion of the Midwest; in addition to Florida and Maine.

States that encourage the consideration of roundabouts – as denoted in yellow – stretch from the Pacific Ocean, through the Midwest towards Pennsylvania.

States that require the evaluation of roundabouts – as denoted in green – are found in Washington to the Northwest, Minnesota and Wisconsin in the northern Midwest, Georgia in the Southeast and Maryland in the Mid-Atlantic.

Alaska and Virginia both require justification when a roundabout is not constructed – as denoted in turquoise; and states with strong roundabout policies – as denoted in blue – are concentrated in the Northeastern United States.

CHAPTER 4

DATA COLLECTION METHODOLOGY

This section outlines the data collection efforts for this study. The purpose of this effort was to acquire the data necessary to analyze and discuss the status of statewide roundabout programs and policies in the United States. In order to do so, several data sources were necessary, including:

- The number of roundabouts in each state
- The number of fatalities at roundabouts in each state
- The current guiding roundabout policy type for each state
- The estimated population for each state
- The annual Vehicle Miles of Travel (VMT) for each state
- The number of roadway (centerline) miles for each state, broken down by functional classification

The following subsections describe the data collection efforts undertaken to acquire the previously described data.

4.1 The number of roundabouts in each state

The number of roundabouts constructed in each state is by nature a dynamic, ever increasing number. The subsequent subsections detail the steps undertaken to identify the number of roundabouts constructed in each state.

4.1.1 Kittelson & Associates, Inc. Roundabout Inventory Database

The first step undertaken to calculate the number of roundabouts in each state was to consult a roundabout inventory database maintained by Kittelson & Associates, Inc.

(KAI). The KAI database attempts to record every existing, planned, proposed and removed roundabout in North America, and at a minimum seeks to include the intersection where the roundabout is located, including the latitude and longitude, and the year the roundabout was constructed. Figure 8 displays the roundabout inventory database search tool, Figure 9 displays example search results from the database, and Figure 10 displays an example listing of the roundabout details available in the database.

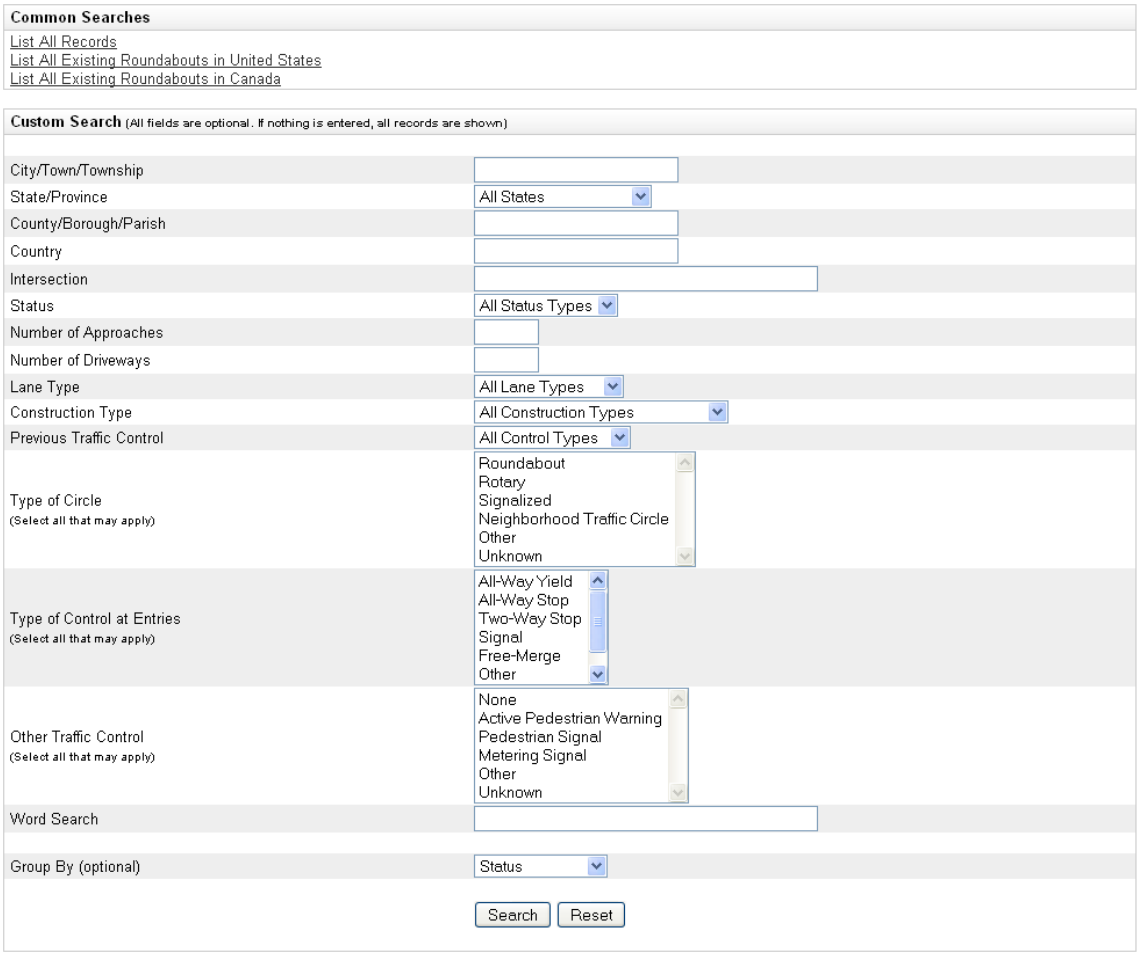

Figure 8. KAI roundabout inventory database search tool (10)

MD	Anne Arundel	Annapolis Junction	MD 31/Guilford Rd.	Single-Lane	Edit
MD	Anne Arundel	Deale	MD 256/MD 258	Single-Lane	Edit
MD	Anne Arundel	Fort Meade	MD 32/Samford Rd.	Single-Lane	Edit
MD	Anne Arundel	Hanover	MD 295 NB Ramps/Arundel Mills Blvd.	Multi-Lane	Edit
MD	Anne Arundel	Hanover	MD 295 SB Ramps/Arundel Mills Blvd.	Multi-Lane	Edit
MD	Anne Arundel	Lothian	MD 2/MD 408/MD 422	Single-Lane	Edit
MD	Anne Arundel	Odenton	MD 175/MD 677/Higgins Dr.	Multi-Lane	Edit
MD	Baltimore	Catonsville	MD 372/Hilltop Rd./Entrance to UMBC	Single-Lane	Edit
MD	Baltimore	Lutherville-Timonium	MD 139 (Charles St.)/Bellona Ave.	Multi-Lane	Edit
MD	Baltimore	Towson	MD 45/MD 146/Joppa Rd./Allegheny Ave.	Multi-Lane	Edit
MD	Calvert	Saint Leonard	Calvert Beach Rd./Saint Leonard Rd.	Single-Lane	Edit
MD	Caroline	Federalsburg	MD 307/MD 313/MD 318	Single-Lane	Edit
MD	Carroll	Hampstead	MD 88/MD 833	Single-Lane	Edit
MD	Carroll	Taneytown	MD 140/MD 832/Antrim Blvd.	Multi-Lane	Edit
MD	Cecil	Elkton	MD 213 (Fair Hill Rd.)/Leeds Rd./Elk Mill Rd. (Lanzi Circle)	Single-Lane	Edit
MD	Cecil	Rising Sun	MD 273 (Rising Sun Rd.)/MD 276 (Jacob Tome Memorial Hwy.)	Single-Lane	Edit
MD	Charles	Hughesville	MD 5 NB Ramps/MD 231	Multi-Lane	Edit
MD	Charles	Hughesville	MD 5 SB Ramps/MD 231	Multi-Lane	Edit
MD	Frederick	Brunswick	MD 17/A St./B St./Maryland Ave.	Single-Lane	Edit
MD	Frederick	Rosemont	MD 17/MD 180	Single-Lane	Edit
MD	Frederick	Urbana	MD 80/Sugarloaf Pkwy./Bennett Creek Blvd.	Multi-Lane	Edit
MD	Frederick	Urbana	Bennett Creek Ave./Bennett Creek Rd.	Single-Lane	Edit
MD	Frederick	Urbana	Bennett Creek Ave./Bennett Creek Blvd.	Single-Lane	Edit
MD	Frederick	Urbana	Sugarloaf Pkwy./(unknown)	Single-Lane	Edit
MD	Frederick	Urbana	Sugarloaf Pkwy./Denison St.	Multi-Lane	Edit
MD	Frederick	Urbana	Sprigg St./(unknown)	Single-Lane	Edit
MD	Frederick	Urbana	Bush Creek Dr./Major Smith Ln.	Single-Lane	Edit
MD	Harford	(unincorporated)	Tollgate Rd./Westover Ln./Crisfield Dr.	Single-Lane	Edit
MD	Harford	Abingdon	Tollgate Rd./Montrose Way	Single-Lane	Edit
MD	Harford	Abingdon	Tollgate Rd./Singer Rd.	Single-Lane	Edit
MD	Harford	Bel Air	Moores Mill Rd./Brushing Ln.	Single-Lane	Edit
MD	Harford	Bel Air	Tollgate Rd./Marketplace Dr.	Single-Lane	Edit
MD	Harford	Bel Air	MD 7/Holly Oaks Drive	Single-Lane	Edit
MD	Harford	Bel Air	Tollgate Rd./Wheel Rd.	Single-Lane	Edit
MD	Harford	Forest Hill	MD 23/Commerce Rd.	Single-Lane	Edit
MD	Harford	Fountain Green	Prospect Mill Rd./Wagner Rd.	Single-Lane	Edit
MD	Harford	Frogtown	Mardic Dr./Willrich Ct.	Single-Lane	Edit
MD	Harford	North Harford	MD 165/MD 24	Single-Lane	Edit
MD	Howard	Clarksville	Brighton Dam Rd./Ten Oaks Rd.	Single-Lane	Edit
MD	Howard	Columbia	Trotter Rd./South Wind Cir.	Single-Lane	Edit
MD	Howard	Columbia	Cradlerock Way/Homespun Dr.	Single-Lane	Edit
MD	Howard	Ellicott City	MD 103/MD 100 WB Ramps	Single-Lane	Edit
MD	Howard	Ellicott City	MD 103/MD 100 EB Ramps	Single-Lane	Edit
MD	Howard	Ellicott City	Snowden River Pkwy./MD 100 WB Ramps	Single-Lane	Edit
MD	Howard	Ellicott City	MD 104 (Waterloo Rd.)/MD 100 WB Ramps	Multi-Lane	Edit
MD	Howard	Jessup	MD 32 EB Ramps/Canine Rd.	Single-Lane	Edit
MD	Howard	Jessup	MD 32 WB Ramps/MD 198 (Laurel Fort Meade Rd.)	Multi-Lane	Edit
MD	Howard	Jessup	MD 32 EB Ramps/MD 198 (Laurel Fort Meade Rd.)	Multi-Lane	Edit
MD	Howard	Lisbon	MD 94/Old Frederick Rd. (Lisbon North)	Single-Lane	Edit
MD	Howard	Lisbon	MD 94/MD 144	Single-Lane	Edit
MD	Howard	Scaggsville	MD 216/US 29 SB Ramps	Multi-Lane	Edit
MD	Howard	Scaggsville	MD 216/US 29 NB Ramps	Multi-Lane	Edit

Figure 9. Example search results from the KAI database (10)

Roundabout Details

Site ID: 3

Site Location	
Intersection	MD 94/MD 144
City/Town/Township	Lisbon
State/Province	MD
County/Borough/Parish	Howard
Country	USA
Status	Existing
Latitude	39.337
Longitude	-77.0736

Site Description	
Number of Approaches	4
Number of Driveways	
Type	Single-Lane
Highest Functional Class of intersecting roadways	
Construction	Retrofit
Inscribed Diameter	31 Meters
Type of Circle	
Type of Control	
Other Traffic Control	
Previous Traffic Control	Two-Way Stop
Year of Completion	1993
Site Comments	First roundabout in Maryland. Built initially as temporary, made permanent after one month.

Conatct Information	
Primary Contact	
Name	Michael Niederhauser
Job Title	
Company or Agency	Maryland State Highway Administration
Address	7491 Connelley
City	Hanover
State or Province	MD
Postal Code	21076
Phone Number	(410) 787-5879
Fax Number	(410) 582-9469
Email Address	mniederhauser@sha.state.md.us

Figure 10. Example roundabout details listing in the KAI database (10)

Anecdotal evidence suggests that maintenance of the database has become more difficult in recent years because of the dramatic growth of roundabouts in North America. Furthermore, as roundabouts become more accepted, the new construction of roundabouts becomes less visible, causing roundabouts to be missed by the operators of the database. The database allows anyone with information on a roundabout to enter the roundabout details in the database, but the listing is not shown in the database until it is verified by one of the database operators at KAI. Because of the sheer volume of roundabouts now being constructed in North America, the task of verifying information entered in the database has also become challenging.

By using the database, an initial baseline number of existing roundabouts per state was tabulated.

4.1.2 Roundabout Listserv

Next, an email distribution list, commonly referred to as the roundabout listserv, maintained by Dr. Eugene Russell from Kansas State University was utilized to fill in the information missing from the KAI database. Currently 373 people with some interest in roundabouts currently subscribe to the listserv (33). While subscribers are predominantly transportation engineers who work with roundabouts, people from a variety of professions and backgrounds also subscribe.

By utilizing the listserv, the number of roundabouts for each state was sought out, and unlike the KAI database, the year of construction and the intersection were not sought, making the total number easier to acquire, yet less verifiable. In many cases, the users of the listserv either had numbers that matched the KAI database, or used the KAI database as their tool for tracking roundabouts in their jurisdiction. However, in the case of 20 states, the number of roundabouts denoted by a user of the listserv was higher than found in the KAI database, and consequently, those numbers were utilized.

4.2 The number of fatalities at roundabouts in each state

The number of fatalities at roundabouts in each state was also found on the roundabout listserv. The numbers were compiled over the summer of 2010, and include all known fatalities that have occurred at roundabouts in the United States.

4.3 The current guiding roundabout policy type for each state

The most challenging data collection effort was the pursuit of the guiding roundabout policy type for each state. The typical steps utilized to locate the policy for each state are subsequently described.

First, the website for the state's DOT was located and searched for any mention of roundabouts. Many state DOT websites had a specific page dedicated to roundabouts, but these pages were generally geared towards the general public, and rarely had information on the state's guiding roundabout policy. Next, an attempt was made to locate the state's roundabout guide. Oftentimes, if a state had a statewide roundabout guide, the guiding policy was contained within. After that, the state's roadway design manual (or the equivalent document) was located, and a search for roundabouts in the manual was completed. If roundabouts were included in the roadway design manual, the policy type, if not previously located, was usually found there. In other cases, DOT memos or a specific roundabout policy document was located that described the guiding roundabout policy type for the state. In the absence of any official document, the policy type was either found from some other source document, or inferred based on anecdotal information.

4.4 The estimated population for each state

The estimated populations for each state were found on the United States Census Bureau, Population Estimates website, and are 2009 estimates (34).

4.5 The annual VMT for each state

The annual VMT for each state was found on the Bureau of Transportation Statistics website, and are 2008 estimates (35).

4.6 The number of roadway miles for each state

The number of roadway miles for each state, broken down by functional classification, were found on the Bureau of Transportation Statistics website, and are 2008 estimates (35).

CHAPTER 5

METHODOLOGY

This chapter details the methodology utilized in the research for this thesis. More specifically, the methods used to analyze the statewide roundabout programs and policies are explained and discussed.

5.1 Per Capita Analyses

The first portion of the analyses of the statewide roundabout programs and policies is a per capita analysis. The per capita analysis utilizes the information presented in Chapter 3, and analyzes the strength of the state's roundabout policy based on the number of roundabouts in the state. Then, because states have varying population, VMT and roadway mile totals, the number of roundabouts is divided by these variables to determine if the strength of a roundabout policy has any effect on the number of roundabouts in the state.

5.2 SWOT

Next, a qualitative SWOT analysis was carried out to determine the status of roundabout policies, and potential areas for development. A SWOT analysis is a Strengths, Weaknesses, Opportunities, and Threats assessment of the information presented. A SWOT analysis first involves specifying the objective of the existing policies, and then identifying the internal and external factors that are favorable and unfavorable to achieving the objective. A SWOT analysis can be particularly helpful in identifying areas for development. Further, the SWOT analysis is able to analyze the

existing policies in terms of their likely consequences. Figure 11 displays the factors utilized in a SWOT analysis.

Figure 11. SWOT analysis

The SWOT analysis was carried out through an examination of literature presented in Chapter 2, discussion with personnel in state agencies familiar with their statewide roundabout program, and a review of newspapers and information related to the implementation of roundabouts.

CHAPTER 6

ANALYSIS

The analysis section utilizes the per capita and SWOT analysis previously described in the methodology section. The results of the analysis are subsequently described.

6.1 Per Capita Analyses

As previously mentioned concerning Table 7 in Chapter 3, a relationship between the number of roundabouts and the strength of a roundabout policy is not readily apparent. However, this is somewhat misleading in that the population, VMT and roadway miles between states are also varied. Consequently, a per capita analysis was completed to identify if the existence of a state roundabout policy has an effect on the number of roundabouts constructed in the state on a per capita basis.

6.1.1 Roundabouts per Person

The first per capita analysis completed was the roundabouts per person analysis. In order to make the numbers legible, the outputs were multiplied by one million. Table 9 displays the roundabouts per million persons by state, and Figure 12 displays the number of roundabouts per person by state, with red representing the states with the fewest number of roundabouts per person, and green representing the states with the most number of roundabouts per person.

Table 9. Roundabouts per million persons by state

State	Roundabouts per Million Persons	State	Roundabouts per Million Persons
Alabama	0.2	**Montana**	21.5
Alaska	22.9	**Nebraska**	2.8
Arizona	17.4	**Nevada**	9.8
Arkansas	1.4	**New Hampshire**	7.5
California	3.4	**New Jersey**	1.6
Colorado	47.8	**New Mexico**	4.5
Connecticut	4.5	**New York**	1.6
Delaware	9.0	**North Carolina**	8.6
District of Columbia	30.0	**North Dakota**	3.1
Florida	5.3	**Ohio**	2.3
Georgia	1.4	**Oklahoma**	0.3
Hawaii	9.3	**Oregon**	23.3
Idaho	5.2	**Pennsylvania**	0.2
Illinois	0.2	**Rhode Island**	3.8
Indiana	23.4	**South Carolina**	0.7
Iowa	11.3	**South Dakota**	1.2
Kansas	30.5	**Tennessee**	1.1
Kentucky	0.5	**Texas**	0.6
Louisiana	0.7	**Utah**	57.5
Maine	2.3	**Vermont**	11.3
Maryland	28.1	**Virginia**	9.6
Massachusetts	3.2	**Washington**	28.4
Michigan	4.1	**West Virginia**	-
Minnesota	15.2	**Wisconsin**	20.5
Mississippi	4.7	**Wyoming**	5.5
Missouri	4.2		

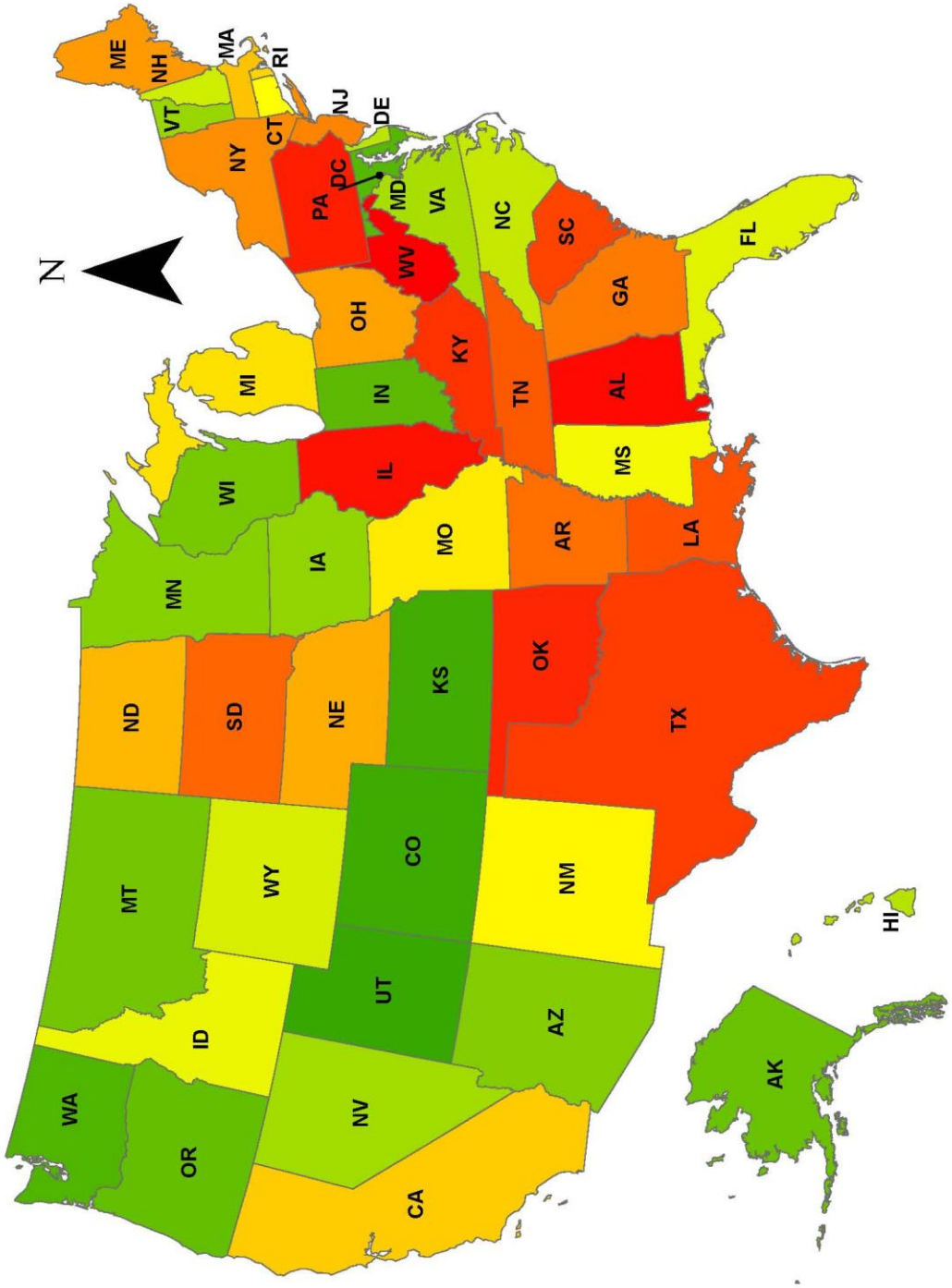

Figure 12. Roundabouts per person

As displayed in Table 9, the number of roundabouts per million persons varies from zero in West Virginia, and 0.2 in Alabama, Illinois and Pennsylvania; to 47.8 in Colorado and 57.5 in Utah. Table 10 displays the roundabouts per million persons' descriptive statistics.

Table 10. Roundabouts per million persons' descriptive statistics

	Roundabouts per Million Persons
Mean*	10.07
Median	4.55
Standard Deviation	12.55

*Represents the mean of the state averages, not the national mean

As displayed in Table 10, the mean – which represents the mean of the state averages, not the national mean – roundabouts per million persons is 10.07. The median of the states is 4.55, with a standard deviation of 12.55. In an attempt to determine if a roundabout policy type correlates to the number of roundabouts per person, the roundabouts per million persons based on policy type was tabulated, and is displayed in Figure 13. Table 11 displays the corresponding numbers.

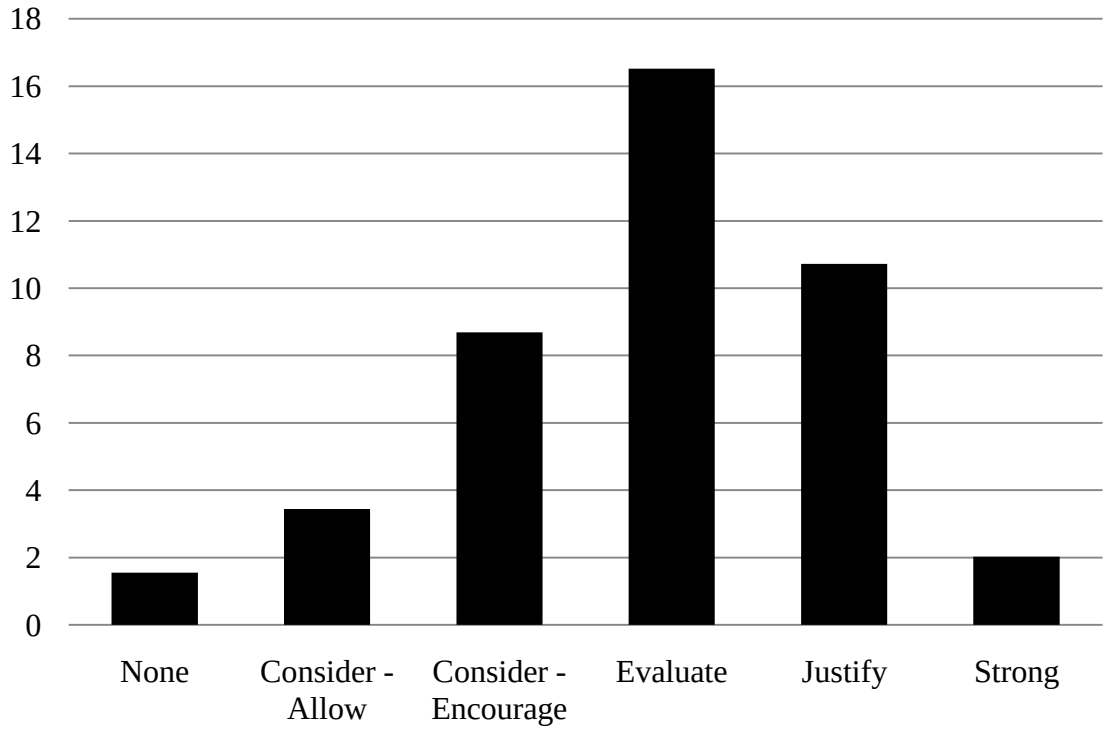

Figure 13. Roundabouts per million persons based on policy type

Table 11. Roundabouts per million persons based on policy type

Policy Type	Number of States	Number of Roundabouts	Total Year 2009 Population	Roundabouts Per Million Persons
None	9	33	21,278,071	**1.6**
Consider - Allow	12	302	87,727,852	**3.4**
Consider - Encourage	19	1,162	133,764,695	**8.7**
Evaluate	6	569	34,438,447	**16.5**
Justify	2	92	8,581,063	**10.7**
Strong	3	43	21,216,422	**2.0**
Total	**51**	**2,201**	**307,006,550**	**7.2**

As displayed in Figure 13, a clear trend begins to emerge as the roundabout policy type begins to strengthen from “None” through “Evaluate”. However, after “Evaluate” the trend breaks down, with the number of roundabouts per million persons based on policy type decreasing with the “Justify” and “Strong” policy types. With only two and three states included in the “Justify” and “Strong” policy type categories, respectively,

including several high population states in the northeast with small geographical footprints in the "Strong" category, it is justifiable that the "Justify" and "Strong" policy type categories would be lower.

Therefore, the "Evaluate", "Justify" and "Strong" policy type categories were combined into an "Analysis" policy type category. The "Analysis" policy type category denotes any state that requires the analysis of a roundabout at an intersection project receiving DOT funding. Figure 14 displays the number of roundabouts per million persons based on combined policy types, and Table 12 displays the tabulated data used in the calculation.

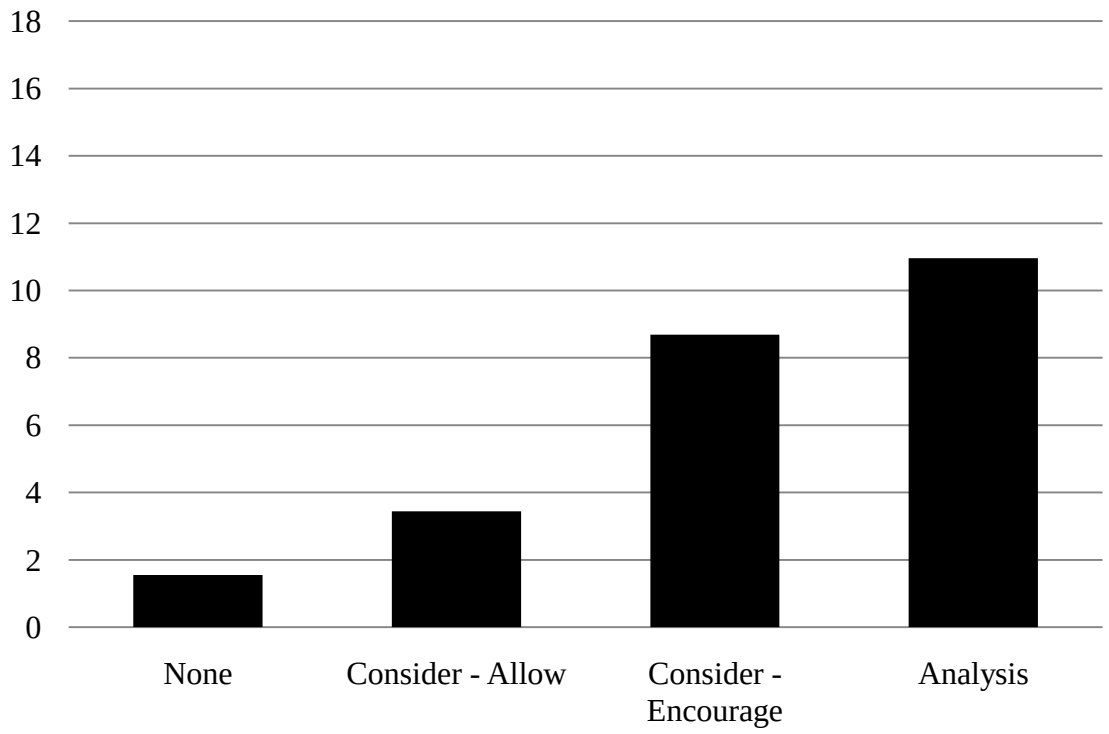

Figure 14. Roundabouts per million persons based on combined policy types

Table 12. Roundabouts per million persons based on combined policy types

Policy Type	Number of States	Number of Roundabouts	Total Year 2009 Population	Roundabouts Per Million Persons
None	9	33	21,278,071	**1.6**
Consider - Allow	12	302	87,727,852	**3.4**
Consider - Encourage	19	1,162	133,764,695	**8.7**
Analysis	11	704	64,235,932	**11.0**
Total	**51**	**2,201**	**307,006,550**	**7.2**

As displayed in Figure 14, the number of roundabouts per million persons based on combined policy types clearly trends upward as the policy type is strengthened. Consequently, it can be inferred that the strengthening of a statewide roundabout policy type is loosely correlated to an increase in the number of roundabouts constructed in the state.

6.1.2 Roundabouts per VMT

The second per capita analysis completed was the roundabouts per VMT analysis. In order to make the numbers legible, the VMT outputs, which were already on a "per-million" basis, were multiplied by one million. Table 13 displays the roundabouts per trillion VMT by state, and Figure 15 displays the number of roundabouts per VMT, with red representing the states with the fewest number of roundabouts per VMT, and green representing the states with the most number of roundabouts per VMT.

Table 13. Roundabouts per trillion VMT by state

State	Roundabouts per Million Persons	State	Roundabouts per Million Persons
Alabama	16.86	**Montana**	1,942.29
Alaska	3,288.80	**Nebraska**	260.82
Arizona	1,866.03	**Nevada**	1,251.20
Arkansas	120.62	**New Hampshire**	766.87
California	384.98	**New Jersey**	190.14
Colorado	5,014.63	**New Mexico**	342.48
Connecticut	504.14	**New York**	238.65
Delaware	891.27	**North Carolina**	796.37
District of Columbia	4,984.77	**North Dakota**	255.75
Florida	498.45	**Ohio**	249.30
Georgia	128.37	**Oklahoma**	20.62
Hawaii	1,167.54	**Oregon**	2,659.26
Idaho	524.56	**Pennsylvania**	27.82
Illinois	28.28	**Rhode Island**	488.58
Indiana	2,113.48	**South Carolina**	60.49
Iowa	1,107.02	**South Dakota**	111.28
Kansas	2,892.99	**Tennessee**	100.76
Kentucky	42.08	**Texas**	67.97
Louisiana	66.53	**Utah**	6,160.01
Maine	206.06	**Vermont**	957.33
Maryland	2,907.87	**Virginia**	923.70
Massachusetts	385.29	**Washington**	3,401.85
Michigan	402.65	**West Virginia**	-
Minnesota	1,379.43	**Wisconsin**	2,018.73
Mississippi	320.29	**Wyoming**	317.56
Missouri	366.18		

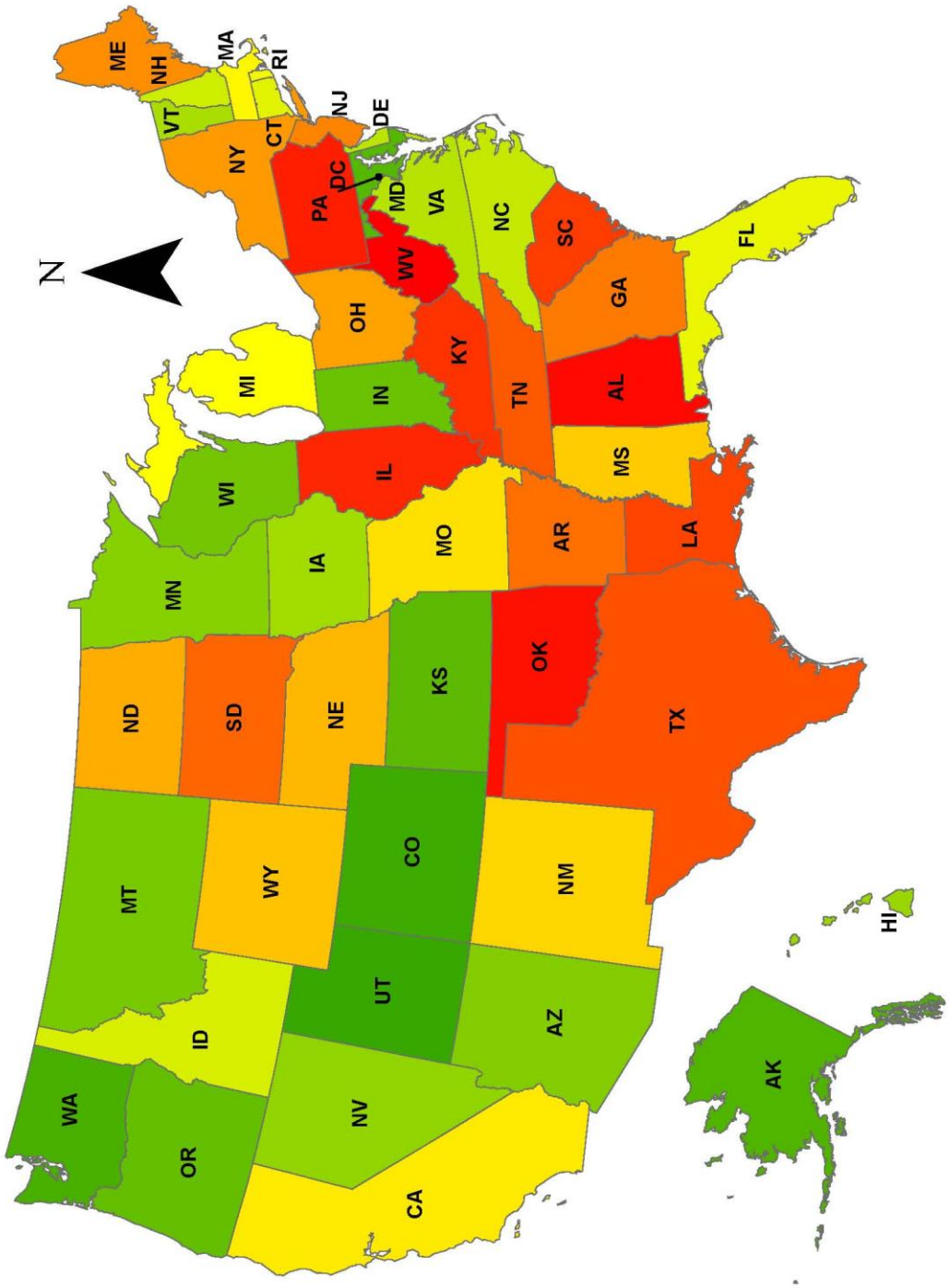

Figure 15. Roundabouts per VMT

As displayed in Table 13, the number of roundabouts per trillion VMT varies from zero in West Virginia, 16.86 in Alabama, and 27.82 in Pennsylvania; to 5,014.63 in Colorado and 6,160.01 in Utah. Table 14 displays the roundabouts per trillion VMT descriptive statistics.

Table 14. Roundabouts per trillion VMT descriptive statistics

	Roundabouts per Trillion VMT
Mean*	1,082.73
Median	402.65
Standard Deviation	1,431.15

*Represents the mean of the state averages, not the national mean

As displayed in Table 14, the mean – which represents the mean of the state averages, not the national mean – roundabouts per trillion VMT is 1,082.73. The median of the states is 402.65, with a standard deviation of 1,431.15. In an attempt to determine if a roundabout policy type correlates to the number of roundabouts per VMT, the roundabouts per trillion VMT based on policy type was tabulated, and is displayed in Figure 16. Table 15 displays the corresponding numbers.

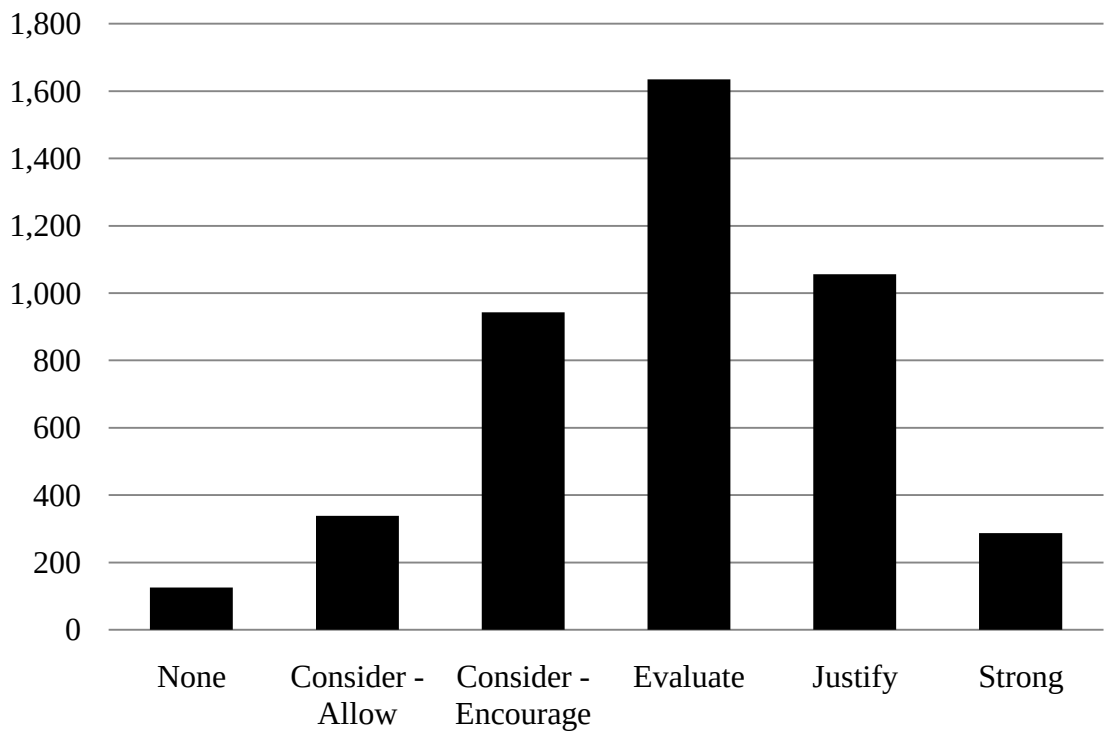

Figure 16. Roundabouts per trillion VMT based on policy type

Table 15. Roundabouts per trillion VMT based on policy type

Policy Type	Number of States	Number of Roundabouts	Total Year 2008 Million VMT	Roundabouts Per Trillion VMT
None	9	33	263,388	**125.29**
Consider - Allow	12	302	892,793	**338.26**
Consider - Encourage	19	1,162	1,232,466	**942.83**
Evaluate	6	569	348,135	**1634.42**
Justify	2	92	87,143	**1055.74**
Strong	3	43	149,584	**287.46**
Total	**51**	**2,201**	**2,973,509**	**740.20**

As displayed in Figure 16, a clear trend begins to emerge as the roundabout policy type begins to strengthen from “None” through “Evaluate”. However, after “Evaluate” the trend breaks down, with the number of roundabouts per trillion VMT based on policy type decreasing with the “Justify” and “Strong” policy types. With only two and three states included in the “Justify” and “Strong” policy type categories, respectively,

including several high population states, and corresponding high VMT, in the northeast with small geographical footprints in the "Strong" category, it is justifiable that the "Justify" and "Strong" policy type categories would be lower.

Therefore, the "Evaluate", "Justify" and "Strong" policy type categories were combined into an "Analysis" policy type category. The "Analysis" policy type category denotes any state that requires the analysis of a roundabout at an intersection project receiving DOT funding. Figure 17 displays the roundabouts per trillion VMT based on combined policy types, and Table 16 displays the tabulated data used in the calculation.

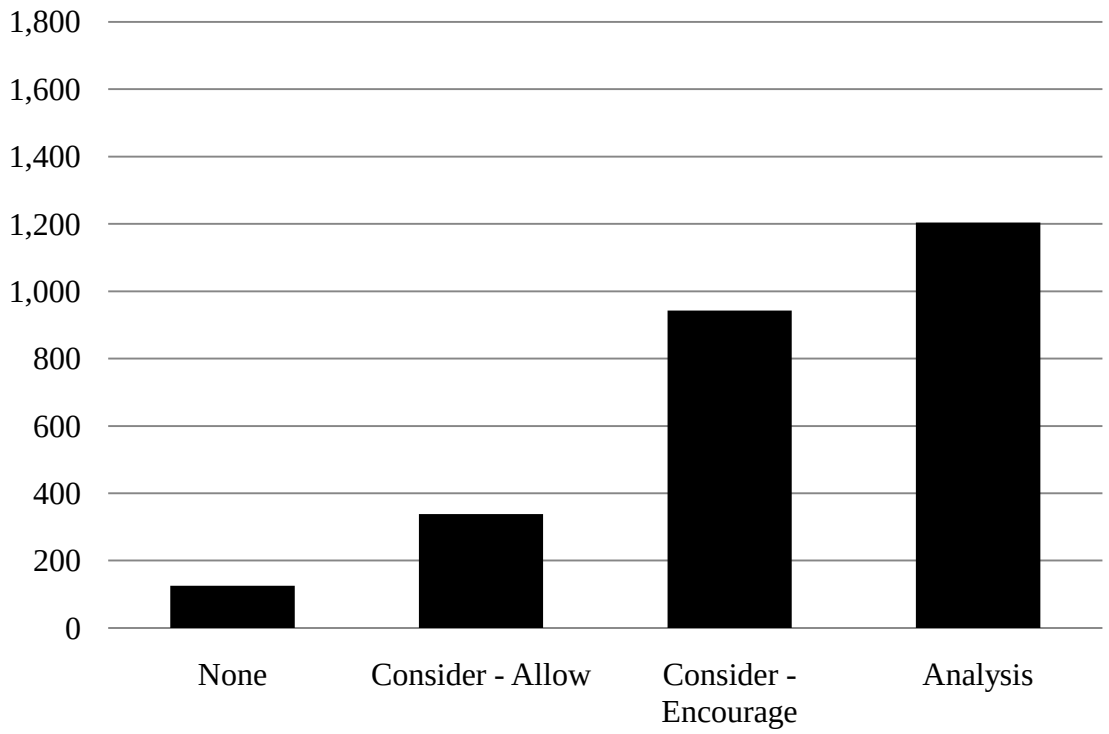

Figure 17. Roundabouts per trillion VMT based on combined policy types

Table 16. Roundabouts per trillion VMT based on combined policy types

Policy Type	Number of States	Number of Roundabouts	Total Year 2008 Million VMT	Roundabouts Per Trillion VMT
None	9	33	263,388	**125.29**
Consider - Allow	12	302	892,793	**338.26**
Consider - Encourage	19	1,162	1,232,466	**942.83**
Analysis	11	704	584,862	**1203.70**
Total	**51**	**2,201**	**2,973,509**	**740.20**

As displayed in Figure 17, the number of roundabouts per trillion VMT based on combined policy types clearly trends upward as the policy type is strengthened. Consequently, it can again be inferred that the strengthening of a statewide roundabout policy type is loosely correlated to an increase in the number of roundabouts constructed in the state.

6.1.3 Roundabouts per Roadway Mile

The third per capita analysis completed was the roundabouts per roadway mile analysis. In order to make the numbers legible, the roadway mile outputs were multiplied by one million. Furthermore, because no roundabouts have, or will be, constructed on interstate highways the number of interstate miles in each state was subtracted from the total number of roadway miles. Table 17 displays the roundabouts per million roadway miles by state, and Figure 18 displays the number of roundabouts per mile, with red representing the states with the fewest number of roundabouts per mile, and green representing the states with the most number of roundabouts per mile.

Table 17. Roundabouts per million roadway miles*

State	Roundabouts per Million Roadway Mile	State	Roundabouts per Million Roadway Mile
Alabama	10.37	**Montana**	287.75
Alaska	1,123.04	**Nebraska**	53.69
Arizona	1,940.21	**Nevada**	779.94
Arkansas	40.34	**New Hampshire**	633.71
California	740.95	**New Jersey**	365.33
Colorado	2,748.76	**New Mexico**	133.56
Connecticut	761.29	**New York**	283.77
Delaware	1,281.85	**North Carolina**	779.00
District of Columbia	12,056.26	**North Dakota**	23.18
Florida	825.58	**Ohio**	222.41
Georgia	116.06	**Oklahoma**	8.90
Hawaii	2,784.22	**Oregon**	1,520.77
Idaho	169.57	**Pennsylvania**	25.00
Illinois	21.85	**Rhode Island**	631.81
Indiana	1,588.28	**South Carolina**	45.86
Iowa	299.71	**South Dakota**	12.27
Kansas	615.44	**Tennessee**	76.86
Kentucky	25.65	**Texas**	52.78
Louisiana	49.84	**Utah**	3,655.47
Maine	133.56	**Vermont**	496.42
Maryland	5,177.16	**Virginia**	1,044.20
Massachusetts	591.02	**Washington**	2,283.66
Michigan	340.46	**West Virginia**	-
Minnesota	582.56	**Wisconsin**	1,016.64
Mississippi	188.71	**Wyoming**	110.32
Missouri	194.50		

*Not including interstate miles

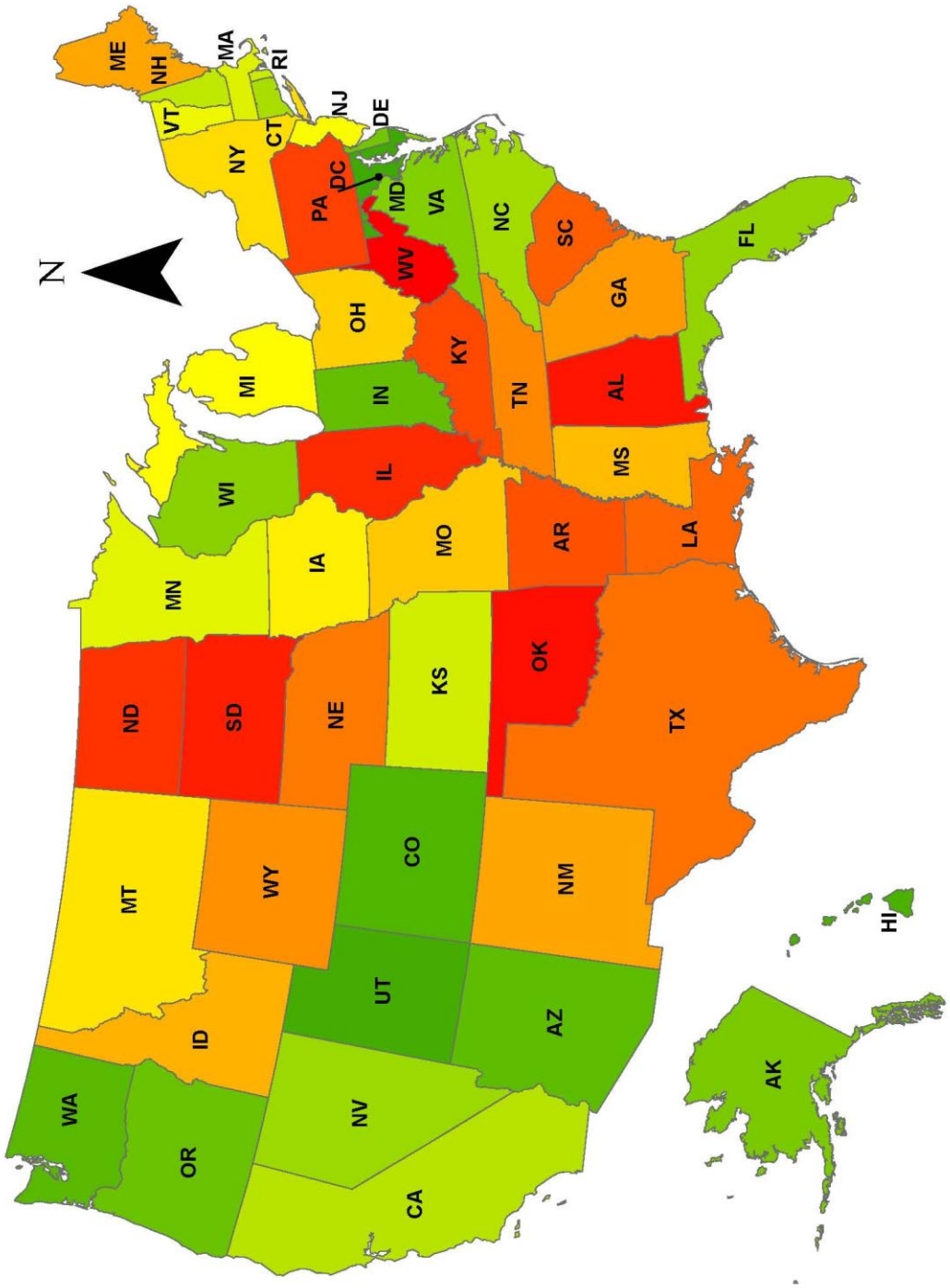

Figure 18. Roundabouts per mile*

*Not including interstate miles

As displayed in Table 17, the roundabouts per million roadway miles varies from zero in West Virginia, 10.37 in Alabama, and 23.18 in North Dakota; to 5,177.16 in Maryland and 12,056.26 in the District of Columbia. Table 18 displays the roundabouts per million roadway miles descriptive statistics.

Table 18. Roundabouts per million roadway miles* descriptive statistics

	Roundabouts per million roadway miles (without interstates)
Mean**	959.81
Median	340.46
Standard Deviation	1,889.77

* Not including interstate miles
**Represents the mean of the state averages, not the national mean

As displayed in Table 18, the mean – which represents the mean of the state averages, not the national mean – roundabouts per million roadway miles is 959.81. The median of the states is 340.46, with a standard deviation of 1,889.77. In an attempt to determine if a roundabout policy type correlates to the number of roundabouts per roadway mile, the roundabouts per million roadway miles based on policy type was tabulated, and is displayed in Figure 19. Table 19 displays the corresponding numbers.

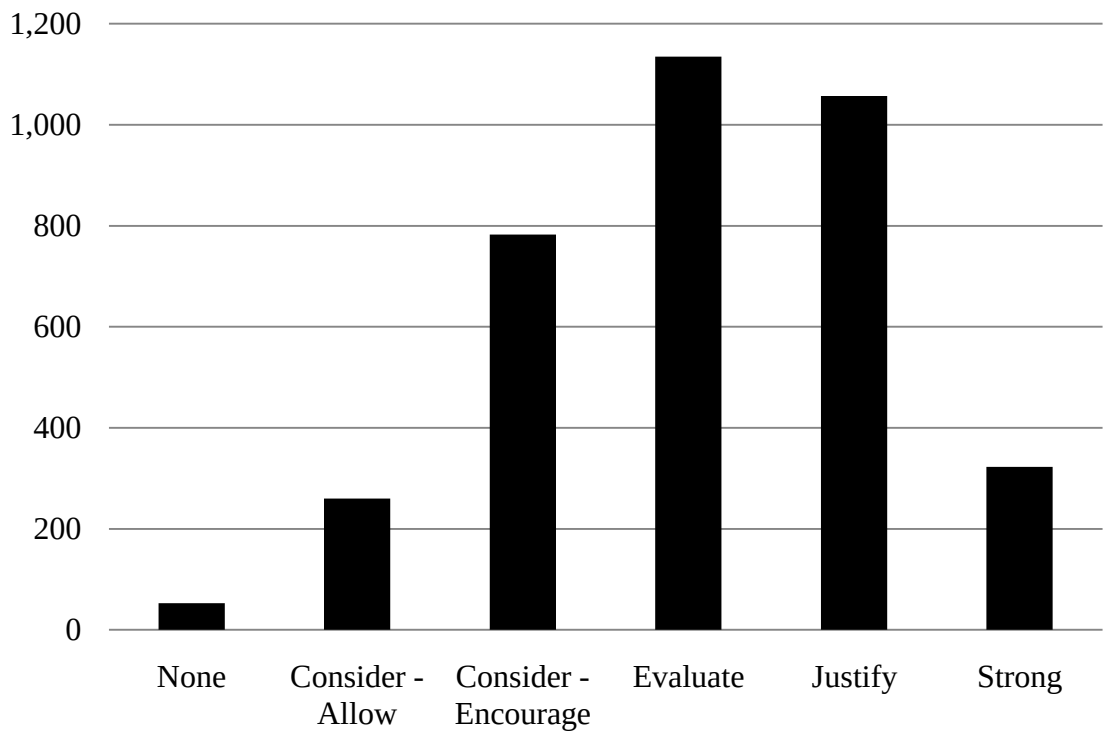

Figure 19. Roundabouts per million roadway miles* based on policy type

* Not including interstate miles

Table 19. Roundabouts per million roadway miles* based on policy type

Policy Type	Number of States	Number of Roundabouts	Total Year 2008 Roadway Miles*	Roundabouts Per Million Roadway Miles*
None	9	33	628,419	**52.51**
Consider - Allow	12	302	1,160,600	**260.21**
Consider - Encourage	19	1,162	1,485,277	**782.35**
Evaluate	6	569	501,503	**1134.59**
Justify	2	92	87,030	**1057.11**
Strong	3	43	133,198	**322.83**
Total	**51**	**2,201**	**3,996,027**	**550.80**

* Not including interstate miles

As displayed in Figure 19, a clear trend begins to emerge as the roundabout policy type begins to strengthen from “None” through “Evaluate”. However, after “Evaluate” the trend breaks down, with the number of roundabouts per roadway mile based on policy

type decreasing with the "Justify" and "Strong" policy types. With only two and three states included in the "Justify" and "Strong" policy type categories, respectively, it is justifiable that the "Justify" and "Strong" policy type categories would be lower.

Therefore, the "Evaluate", "Justify" and "Strong" policy type categories were combined into an "Analysis" policy type category. The "Analysis" policy type category denotes any state that requires the analysis of a roundabout at an intersection project receiving DOT funding. Figure 20 displays the number of roundabouts per roadway mile based on combined policy types, and Table 20 displays the tabulated data used in the calculation.

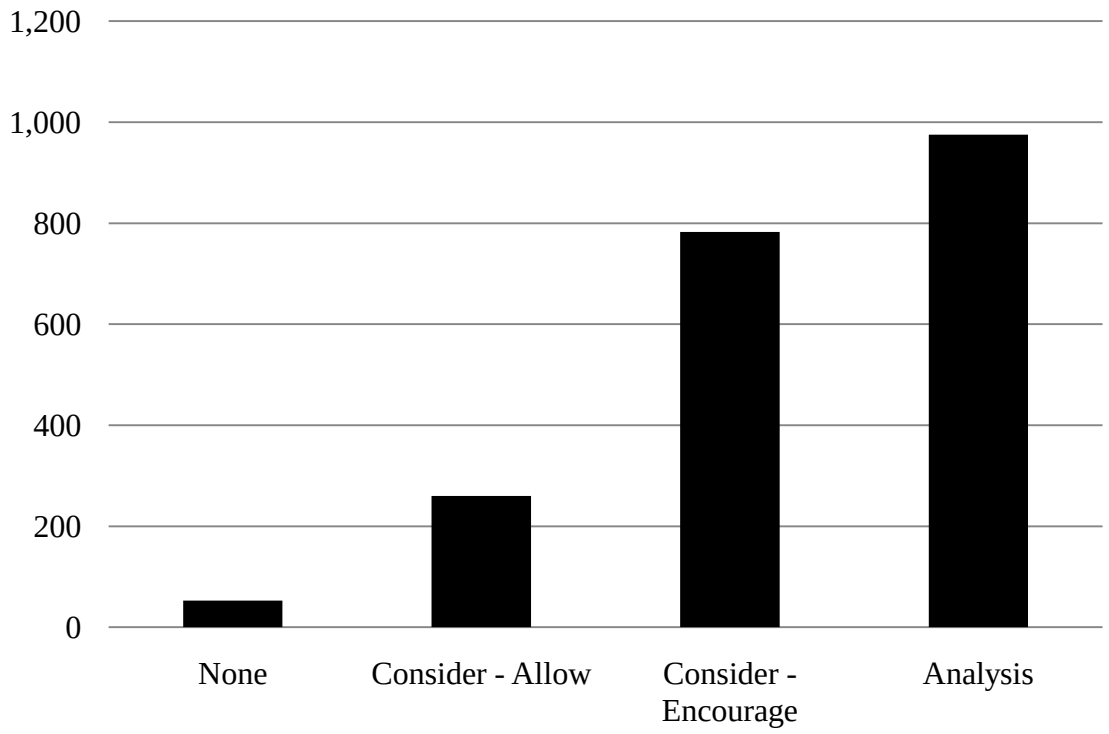

Figure 20. Roundabouts per million roadway miles* based on combined policy type

Table 20. Roundabouts per million roadway miles* based on combined policy type

Policy Type	Number of States	Number of Roundabouts	Total Year 2008 Roadway Miles*	Roundabouts Per Million Roadway Miles*
None	9	33	628,419	**52.51**
Consider - Allow	12	302	1,160,600	**260.21**
Consider - Encourage	19	1,162	1,485,277	**782.35**
Analysis	11	704	721,731	**975.43**
Total	**51**	**2,201**	**3,996,027**	**550.80**

* Not including interstate miles

As displayed in Figure 20, the number of roundabouts per roadway mile based on combined policy types clearly trends upward as the policy type is strengthened. Consequently, it can again be inferred that the strengthening of a statewide roundabout policy type is loosely correlated to an increase in the number of roundabouts constructed in the state.

6.1.4 Fatalities per Roundabout

The fourth and last per capita analysis completed was the fatalities per roundabout analysis. In order to make the numbers legible, the fatality outputs were multiplied by one thousand. Table 21 displays the fatalities per roundabout by state, and Figure 21 displays the number of fatalities per roundabout, with red representing the states with the most number of fatalities per roundabout, and green representing the states with the fewest number of fatalities per roundabout.

Table 21. Fatalities per thousand roundabouts

State	Fatalities per Thousand Roundabouts	State	Fatalities per Thousand Roundabouts
Alabama	-	**Montana**	-
Alaska	-	**Nebraska**	-
Arizona	-	**Nevada**	-
Arkansas	-	**New Hampshire**	-
California	15.9	**New Jersey**	-
Colorado	16.7	**New Mexico**	-
Connecticut	-	**New York**	-
Delaware	-	**North Carolina**	-
District of Columbia	-	**North Dakota**	-
Florida	20.2	**Ohio**	-
Georgia	-	**Oklahoma**	-
Hawaii	-	**Oregon**	-
Idaho	-	**Pennsylvania**	-
Illinois	333.3	**Rhode Island**	-
Indiana	13.3	**South Carolina**	-
Iowa	-	**South Dakota**	-
Kansas	34.9	**Tennessee**	-
Kentucky	-	**Texas**	-
Louisiana	-	**Utah**	-
Maine	-	**Vermont**	-
Maryland	6.3	**Virginia**	13.2
Massachusetts	-	**Washington**	5.3
Michigan	-	**West Virginia**	-
Minnesota	-	**Wisconsin**	8.6
Mississippi	-	**Wyoming**	-
Missouri	-		

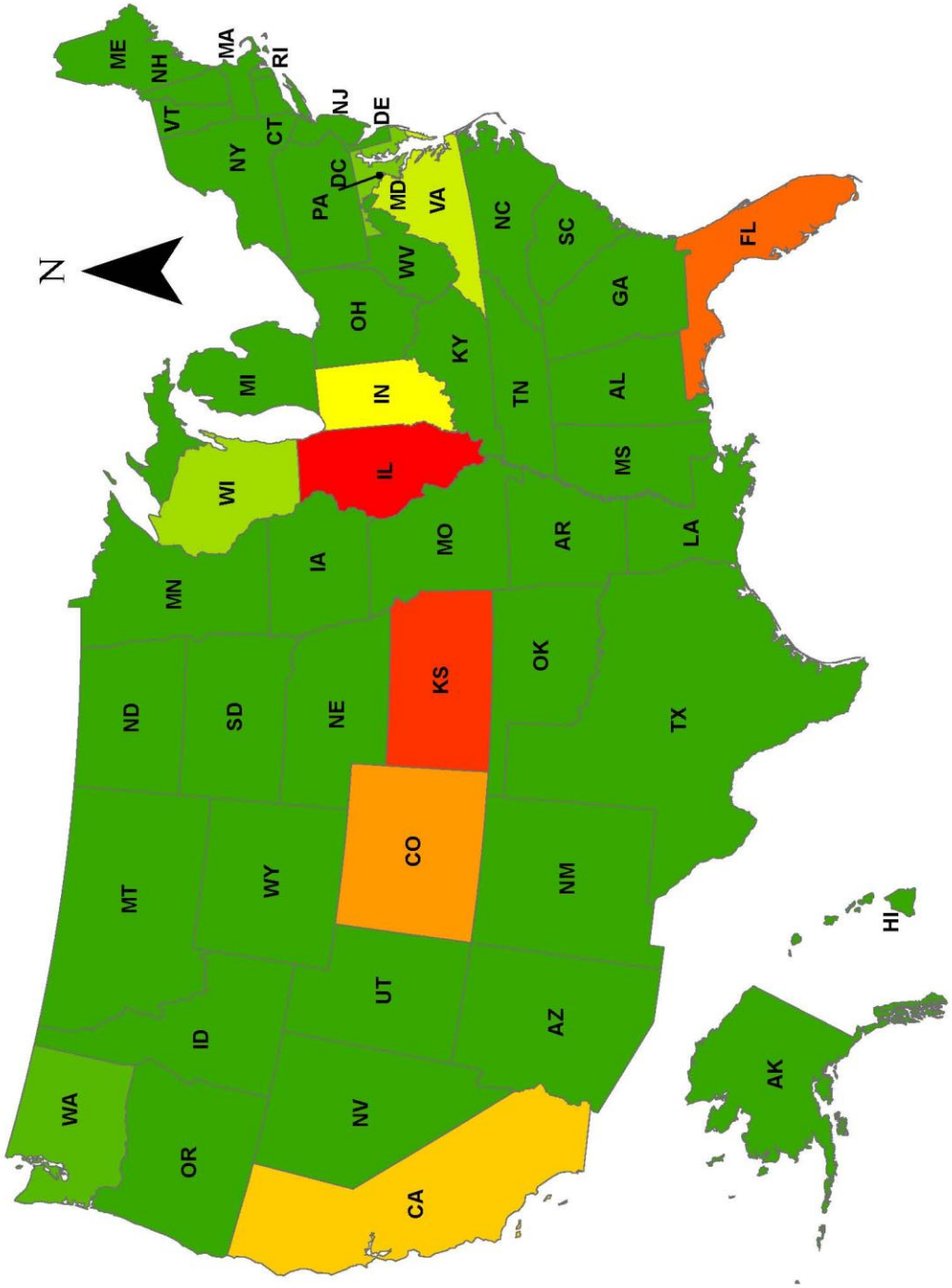

Figure 21. Fatalities per roundabout

As displayed in Table 21, the fatalities per roundabout vary from zero in most states, to 5.3 in Washington, and to 333.3 in Illinois. Table 22 displays the fatalities per roundabout descriptive statistics.

Table 22. Fatalities per thousand roundabouts descriptive statistics

	Fatalities per 1000 roundabouts
Mean*	9.35
Median	-
Standard Deviation	47.25

*Represents the mean of the state averages, not the national mean

As displayed in Table 22, the mean – which represents the mean of the state averages, not the national mean – fatalities per roundabout is 959.81. The median of the states is 340.46, with a standard deviation of 1,889.77. In an attempt to determine if a roundabout policy type correlates to the fatalities per roundabout, the fatalities per thousand roundabouts based on policy type was tabulated, and is displayed in Figure 22. Table 23 displays the corresponding numbers.

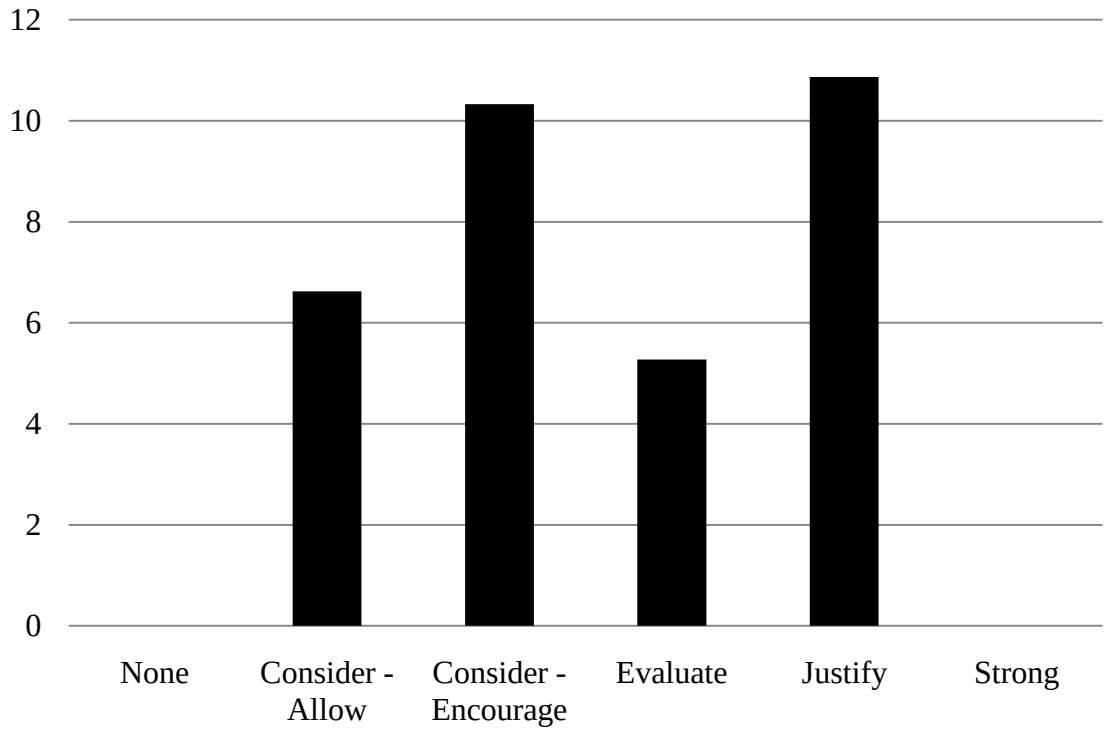

Figure 22. Fatalities per thousand roundabouts based on policy type

Table 23. Fatalities per thousand roundabouts based on policy type

Policy Type	Number of States	Number of Roundabouts	Total Roundabouts Fatalities	Fatalities per 1000 Roundabouts
None	9	33	0	**0.00**
Consider - Allow	12	302	2	**6.62**
Consider - Encourage	19	1,162	12	**10.33**
Evaluate	6	569	3	**5.27**
Justify	2	92	1	**10.87**
Strong	3	43	0	**0.00**
Total	**51**	**2,201**	**18**	**8.18**

As displayed in Figure 22, no trend begins to emerge as the roundabout policy type begins to strengthen from "None" through "Evaluate". However, the "Evaluate", "Justify" and "Strong" policy type categories were combined into an "Analysis" policy type category, in an attempt to see if a trend does begin to emerge. The "Analysis" policy

type category denotes any state that requires the analysis of a roundabout at an intersection project receiving DOT funding. Figure 23 displays the number of fatalities per roundabout based on combined policy types, and Table 24 displays the tabulated data used in the calculation.

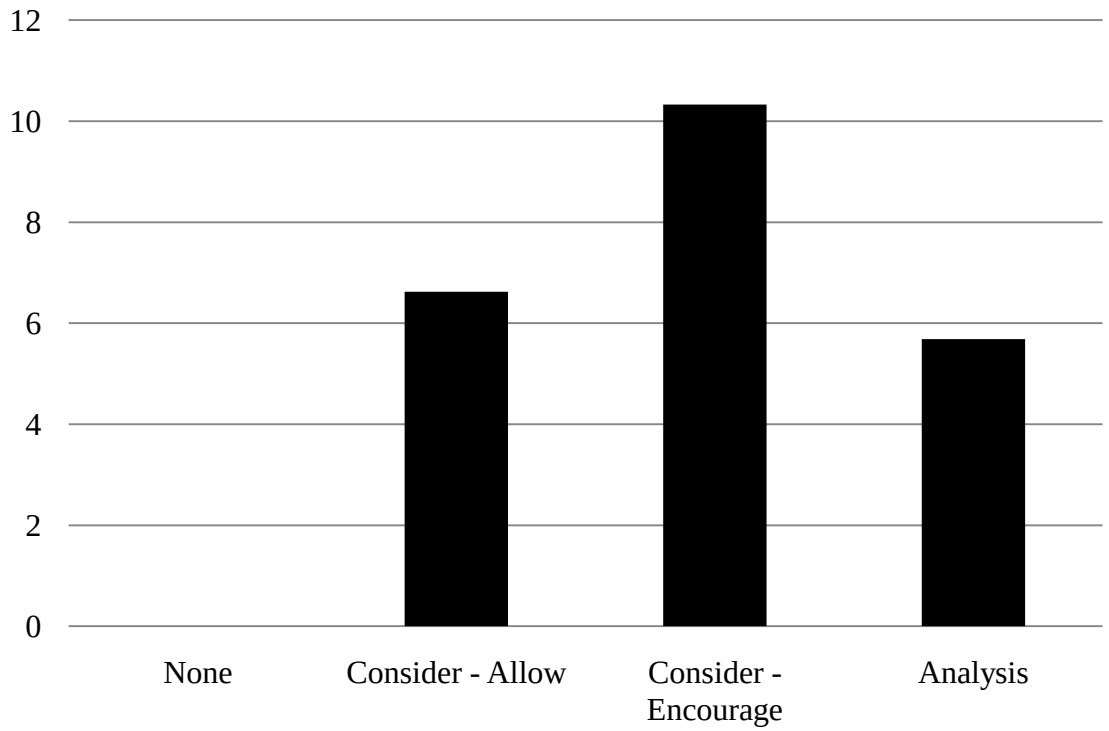

Figure 23. Fatalities per thousand roundabouts based on combined policy type

Table 24. Fatalities per thousand roundabouts based on combined policy type

Policy Type	Number of States	Number of Roundabouts	Total Roundabouts Fatalities	Fatalities per 1000 Roundabouts
None	9	33	0	**0.00**
Consider - Allow	12	302	2	**6.62**
Consider - Encourage	19	1,162	12	**10.33**
Analysis	11	704	4	**5.68**
Total	**51**	**2,201**	**18**	**8.18**

As displayed in Figure 23, the fatalities per roundabout based on combined policy types have no clear trend as the policy type is strengthened. Consequently, it cannot be inferred that the strengthening of a statewide roundabout policy reduces or increases the number of fatalities per roundabout.

6.2 SWOT

A SWOT analysis is being utilized for the qualitative portion of the analysis. In the subsequent four subsections, the Strengths, Weaknesses, Opportunities and Threats are described in an attempt to determine the status of roundabout policies, and potential areas for development.

6.2.1 Strengths

Listed below are the strengths of current roundabout programs and policies that are internal to state agencies and helpful to the advancement of roundabouts in the state.

6.2.1.1 Establishment of a Roundabout Policy

An established statewide roundabout policy has a direct relationship to the advancement of roundabouts in the state. This is partly due to the following reasons:

- An established policy typically indicates that a person or persons in leadership capacity are supportive of the policy.
- An established policy allows roundabout proponents a position of power within the agency by having a regulatory backing.
- An agency with an established roundabout policy could indicate an organization open to change and innovation, which promotes an environment conducive to implementation.

- The enactment of a policy could indicate the breaking down of informal internal barriers, which could hinder the potential implementation.
- With more states enacting policies, new and revised policies have precedents for success.

6.2.1.2 Economic Considerations

With the completion of a life-cycle cost analysis, a roundabout will typically have a lower equivalent cost than other alternatives (4). This is primarily due to the impressive safety record discussed in Section 2.2.1. Furthermore, anecdotal evidence shows that the implementation of a roundabout has demonstrably opened up sites for economic development by relieving capacity constraints at intersections experiencing operational problems (4).

6.2.2 Weaknesses

Listed below are the weaknesses of current roundabout programs and policies that are internal to state agencies and harmful to the advancement of roundabouts in the state.

6.2.2.1 Organizational Structure

While roundabouts are not new to the American transportation system, in some areas of the country their implementation is lagging, perhaps because of the existing organizational structure of state DOT's with long-established departments and structure. The establishment of a roundabout program or policy in these agencies can be seen as an attempt to fit a major organizational change into an old structure.

While some states have a specific goal to build a certain number of roundabouts within a specified timeframe, the use of a time frame, or end goal, in terms of the timing and number of roundabouts to be implemented is rare.

In addition, internal agency education on roundabout design and operation procedures has demonstrably hindered the development and growth of roundabout implementation in some agencies that do not have the skills or expertise necessary to plan for, design, or construct roundabouts (36). In addition, a dependence on inside specialists could lead to a limited point of view and reduce the possibility of successful change or innovation in roundabout advancements.

Furthermore, anecdotal evidence indicates that internal strife between proponents of roundabouts and traffic signals continues to hinder the growth of roundabout programs and policies, and may be hindering potential innovation, especially in the further development of signalized roundabouts.

6.2.2.2 Initial Capital Cost

The initial construction cost of a roundabout tends to be higher than the initial construction cost of other alternatives, making roundabouts tough to justify in a short-term programming evaluation process. This is primarily related to the "footprint" of a roundabout being larger than that of other alternatives, causing acquisition costs associated with needed right-of-way to construct the roundabout to be higher.

6.2.3 Opportunities

Listed below are the opportunities of current roundabout programs and policies that are external to state agencies and helpful to the advancement of roundabouts in the state.

6.2.3.1 Policy

The creation of a roundabout policy further facilitates the implementation of roundabouts, as previously demonstrated. The implementation of a roundabout policy allows for the development of uniform and simplified procedures, and standards and regulations, thereby further increasing the chance for successful implementation of roundabouts. Furthermore, the establishment of roundabout policy validates the roundabout as an alternative.

6.2.3.2 Public Perception, Validation and Acceptance

After the construction of roundabouts in a jurisdiction, the public perception of roundabouts typically swings from negative to positive. The public perception can be further enhanced by the media, who, when utilized positively, can further the successful implementation and growth of roundabout programs and policy. Lastly, as roundabouts begin to be incorporated in driver education classes and state drivers' manuals, roundabouts will be further integrated in the fabric of the transportation system and the understanding of the driver

6.2.3.3 Safety

Roundabout safety data has and continues to show consistent dramatic reductions in crashes, especially in the number of severe and fatal crashes. With over 20 years of United States data consistent with international safety data, it appears as though roundabout safety data is sustainable, and perhaps the best reason for the further advancement of roundabouts in the United States.

6.2.4 Threats

Listed below are the threats of current roundabout programs and policies that are external to state agencies and harmful to the advancement of roundabouts in the state.

6.2.4.1 Public Perception

Negative public perception continues to be the key impediment to the construction of roundabouts in a jurisdiction, especially in areas without previous roundabout installations. In addition, the media is able to give a very audible voice to opponents who seek to slow down or stop the implementation of roundabouts, and can compound the negative public perception.

6.2.4.2 Institutional Change

Institutional change is also a barrier in the implementation of roundabouts, as evidenced by driver education classes that have been slow to adapt to the implementation of roundabouts, and driver's license renewal procedures, which largely do not require drivers to demonstrate knowledge of changes to the roadway environment. Furthermore, state driver manuals have been slow to adapt to the implementation of roundabouts, in addition to other documents like the MUTCD, where roundabouts were not incorporated until 2009, and the HCM, which did not reference roundabouts until the 2010 edition.

6.2.4.3 Private Sector Expertise

A large amount of roundabout expertise is currently located in the private sector, which could be hindering the development of roundabout programs and policy within the state agencies. It is in the best interest of practitioners in the private sector to retain their

roundabout expertise to ensure a continued need by public sector organizations to utilize the private sector expertise.

6.2.4.4 Driver Characteristics

Drivers with physical impediments including: narrowing of the visual field; poor contrast sensitivity; reduced arm and leg strength; limited head/neck flexibility; slower decision making or "complex" reaction time, problems with selective attention, divided attention, and attention switching; and slower visual information processing speed, have had issues with adapting to constructed roundabouts (37). Moreover, as referenced previously, visually-impaired pedestrians and the Access Board continue to state their legitimate concerns with the safety of multilane roundabouts for all users

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

As demonstrated throughout this thesis, the modern roundabout has firmly entrenched itself as a sustaining part of the transportation system due to its impressive safety and operational record. With the proper planning, oversight and resolve, a roundabout program can be ensured of continued success and sustained practice. This section provides lessons learned based on the literature reviewed and the analysis performed in this thesis. Next, these lessons learned are used to form the listed recommendations.

7.1 Lessons Learned

7.1.1 Policy

As discussed in Chapter 6, the strength of a statewide roundabout policy is directly correlated to the number of roundabouts in a state, on a per capita, per VMT, and per roadway mile basis. While a policy is not necessary to implement roundabouts in the state, it certainly helps. A policy also helps to ensure the continuation of the roundabout program, especially in the event one of the early roundabout champions leaves the agency. Further, the formation of a policy helps to institutionalize roundabouts in the states, and formally embeds roundabouts in the state DOT.

7.1.2 Internal Support

With or without a statewide roundabout program or policy, having the support from a person with a significant amount of authority in the agency helps to ensure the continued implementation of roundabouts in the state. This person's role could be either a

formal role with a title or position, or an informal role, where the individual could possibly influence decisions through other unofficial means, such as withholding signal permits if a roundabout alternative is not considered.

7.1.3 Sustainability

Roundabouts can and should be utilized as key components in sustainability plans being developed in growing numbers by state DOTs. Roundabouts are able to address the triple-bottom line components of sustainability, including economic, social and environmental considerations in favorable ways.

7.1.4 Perception

Public perception and acceptance of roundabouts is the biggest hurdle a roundabout program must overcome. It is imperative that the first few roundabouts constructed in a jurisdiction are accompanied with intensive public meetings and public education. In addition to public acceptance, internal agency acceptance of roundabouts is necessary, and this can also be addressed through education.

7.1.5 Safety

Roundabout safety data has and continues to show consistent dramatic reductions in crashes, especially in the number of severe and fatal crashes. With over 20 years of United States data consistent with international safety data, it appears as though roundabout safety data is sustainable, and is perhaps the best reason for the further advancement of roundabouts in the United States.

7.2 Recommendations

The following recommendations were developed based on the analysis performed and a synthesis of literature, and are categorized by recommendation type.

7.2.1 Policy

- A statewide roundabout policy should be strongly considered by states seeking to expand significantly the number of roundabouts in their jurisdiction.
- A statewide roundabout policy that requires the analysis of roundabouts ensures the continuation of a roundabout program, and should be considered for development by any state agency commencing a state roundabout program.

7.2.2 Institutionalization of Roundabouts

- State DOTs seeking to expand the number of roundabouts in their jurisdiction should consider adopting a goal for a certain number of roundabouts to be constructed in a specified period, in order to institutionalize the use of roundabouts.
- The use of life-cycle cost analyses not only makes roundabouts a more feasible intersection alternative, but also is good engineering, and should be utilized.
- Regardless of how a jurisdiction was introduced to roundabouts, it is important that support for roundabouts come from a person within the jurisdiction with enough authority to ensure the continuation of the program.

7.2.3 Education

- In addition to focusing on public education, internal agency education is also necessary to ensure quality design and the continuation of the use of roundabouts as a feasible intersection alternative.

7.2.4 Formation of a Program or Policy

- The formation of a state roundabout program should be started only after a comprehensive assessment of the potential for the program is completed, and a detailed implementation plan is established.
- A state roundabout program should not be started hastily, but instead with a judicious and meticulous overview of the potential pitfalls of a program
- Further, a new program should consider locations where the successful implementation of a roundabout can be ensured, such as sites with existing safety problems.
- States with relatively few roundabouts should look specifically at sites with existing safety issues in order to both ensure successful implementation of roundabouts in the state, but also to maximize the benefits provided by roundabouts.
- As states pursue the further use of roundabouts, they should utilize identified successful implementation procedures, and should be cognizant of reasons for implementation failure, as identified in Section 2.5.

7.2.5 Feasibility Studies and Design Review

- A feasibility study of every proposed roundabout, including a comparison of the roundabout alternative to other potential intersection types, is needed to ensure continued success with roundabouts in the jurisdiction.
- Every roundabout proposed in a jurisdiction with an established roundabout program should be reviewed by a central source with enough roundabout expertise to ensure quality and consistency of roundabout design throughout the jurisdiction.
- Similarly, state design reviews ensure consistency throughout the jurisdiction, and many local jurisdictions do not have the proper experience with roundabouts to do adequate design reviews.

APPENDIX A.

ROUNDABOUT NUMBER AND POLICY SOURCES

State	Number of Roundabouts Source	Policy Text	Policy Source
Alabama	Roundabout Listserv (38)	NA	NA
Alaska	Alaska DOT&PF website (32)	"Roundabout First" policy. Requires designers to provide a written justification of any decision to install a traffic signal instead of a single lane roundabout.	Alaska DOT&PF roundabout website (32)
Arizona	Roundabout Listserv (38)	After ADOT assesses the input from the first two items above, ADOT staff will then determine whether or not to "consider" roundabouts.	ADOT roundabout website (39)
Arkansas	KAI Database (10)	Consider… use of roundabouts, as appropriate	Arkansas' Strategic Highway Safety Plan (40)
California	Roundabout Listserv (38)	Use of roundabouts on the State Highway system may be considered for the primary purpose of enhancing safety and operational characteristics at intersections.	Design Information Bulletin Number 80-01 Roundabouts (41)
Colorado	Roundabout Listserv (38)	Inferred	NA
Connecticut	KAI Database (10)	Those locations which meet or nearly meet [signal] warrants, should be given consideration for roundabout installation. Intersections that are, or proposed to be, all-way stop controlled may also be good candidate locations for a roundabout	Use of Roundabouts on State Highways Memorandum (42)
Delaware	Roundabout Listserv (38)	The potential benefits of reductions in injuries and costs associated with crashes are sufficient alone to recommend modern roundabouts as a first option when safety, capacity, or traffic calming are chief reasons for intersection projects	Delaware Department of Transportation Guidelines on Roundabouts (43)
District of Columbia	KAI Database (10)	Inferred	NA
Florida	KAI Database (10)	Three general questions must be answered to justify a roundabout as the most appropriate form of control at any intersection: (1) Will a roundabout be expected to perform better than other alternative control modes? In other words, will it reduce delay, improve safety or solve some other operational problem? (2) Are there factors present to suggest that a roundabout would be a more appropriate control, even if delays with a roundabout are slightly higher? (3) If any contraindicating factors (as described below) exist, can they be resolved satisfactorily? If these questions may be answered favorably, then a roundabout should be considered as a logical candidate control mode.	Florida Roundabout Guide (44)
Georgia	Modern Roundabouts in Georgia (45)	Roundabouts are the preferred safety and operational alternative for a wide range of intersections of public roads. A roundabout shall be considered as an alternative in the following instances: (1) Any intersection in a project that is being designed as new or is being reconstructed. (2) All existing intersections that have been identified as needing major safety or operational improvements. (3) All signal requests at intersections (provide justification in the Traffic Engineering Study if a roundabout is not selected).	Modern Roundabouts in Georgia (45) f
Hawaii	Roundabout Listserv (38)	[Roundabouts] should be considered as alternatives to stop lights and stop signs	News Article (46)
Idaho	KAI Database (10)	None	Inferred from Roundabout Listserv Email
Illinois	KAI Database (10)	roundabouts be considered as an alternative intersection during all intersection improvements	Illinois Center for Transportation: Roundabout Evaluation and Design: A Site Selection Procedure (47)
Indiana	Roundabout Listserv (38)	A roundabout should be considered as one potential intersection option within an INDOT-sponsored or -funded planning study or project since it offers improved safety, cost savings, and enhanced traffic operations.	The Indiana Design Manual (48)
Iowa	Roundabout Listserv (38)	Promote innovative intersection designs such as roundabouts and other new configurations	Iowa Comprehensive Highway Safety Plan (CHSP) (49)

Kansas	Roundabout Listserv (38)	When planning for intersection improvements, a variety of improvement alternatives should be evaluated, in addition to roundabouts, to determine whether a roundabout is the most appropriate alternative.	Kansas Roundabout Guide (50)
Kentucky	KAI Database (10)	A modern roundabout is an alternative form of intersection control to traffic signals and multi-way stop control intersections. Therefore, roundabouts may be considered only when these intersection control types are warranted.	Highway Design: INTERSECTION—At Grade Intersections: Modern Roundabouts (51)
Louisiana	KAI Database (10)	Inferred	Steps in Marketing Plan Development Process (52)
Maine	KAI Database (10)	Inferred	Maine's Roundabouts Website (53)
Maryland	Roundabout Listserv (38)	SHA has adopted a policy that roundabouts will be considered at all intersections where improvements are being considered.	Maryland Roundabout Program: Early Years and Program Growth (4)
Massachusetts	KAI Database (10)	Roundabouts can be appropriate design alternative to both stop-controlled and signal-controlled intersections. … At higher combinations of major street and minor street volume, traffic signals become the common traffic control measure. Roundabouts should also be considered in these situations.	Massachusetts Highway Design Guide (54)
Michigan	KAI Database (10)	Roundabouts should be considered as one potential intersection option within MDOT-sponsored or funded planning studies/design projects since they offer improved safety, cost savings, and enhanced traffic operations in many situations.	MDOT Roundabout Guidance Document (55)
Minnesota	News Article (56)	In general terms, any intersection – whether in an urban or rural environment – that meets the criteria for additional traffic control beyond a thru stop condition, also qualifies for evaluation as a modern roundabout. Therefore, in any planning process for an intersection improvement where a traffic signal or a 4-way stop is under consideration, a modern roundabout should likewise receive serious consideration. Additionally, roundabouts should always be considered as an improvement strategy for existing 4-way stop or signal-controlled intersections with safety or operational problems.	MD/DOT Road Design Manual: Chapter 12: Design Guidelines for Modern Roundabouts (57)
Mississippi	KAI Database (10)	NA	NA
Missouri	Roundabouts of Kansas City (58)	The process of selecting a roundabout as the preferred form of traffic control for a given intersection has three stages. If a roundabout is not "preferred" at any one of these stages, it will cease to be considered as a viable form of traffic control at the given location.	MoDOT Engineering Policy Guide (59)
Montana	Roundabout Listserv (38)	Inferred	Montana Traffic Engineering Manual (60)
Nebraska	KAI Database (10)	The Traffic Engineering Division conducts an engineering study to evaluate the operation of an intersection and to determine the appropriate traffic control to be provided.	Nebraska Department of Roads: Roundabouts (61)
Nevada	KAI Database (10)	In a continual effort to provide the safest roadways, the Nevada Department of Transportation installs roundabouts at selected state roadway intersections to improve safety and mobility.	Nevada DOT Roundabout Website (62)
New Hampshire	KAI Database (10)	Roundabouts can be placed at an intersection under any type of operational control. Due to the improved safety, operation and capacity benefits of roundabouts it shall be standard procedure at the NH DOT to evaluate any intersection considering signal control to see if a roundabout would be beneficial.	NH DOT Supplemental Design Criteria (63)
New Jersey	KAI Database (10)	Inferred	New Jersey FIT: Future In Transportation (64)
New Mexico	KAI Database (10)	Inferred	New Mexico Department of Transportation – Driving in Roundabouts (65)
New York	KAI Database (10)	When the analysis shows that a roundabout is a feasible alternative, it should be considered the Department's preferred alternative due to the proven substantial safety benefits and other operational benefits.	Highway Design Manual (66)
North Carolina	Roundabout Listserv (38)	The choice of using a roundabout is made on acase-by-case basis. NCDOT evaluates traffic volumes and crashes at each candidate intersection individually to determine if a roundabout would be the most effective solution.	Traffic Engineering: Policies, Practices and Legal Authority Resources (67)
North Dakota	KAI Database (10)	NA	NA

Ohio	Roundabout Listserv (38)	Inferred	Design Manual (68)
Oklahoma	KAI Database (10)	NA	NA
Oregon	KAI Database (10)	Asks everyone to give serious consideration to intersection control alternatives beyond merely traffic signals.	Intersection Control Using Roundabouts (69)
Pennsylvania	KAI Database (10)	When planning for intersection improvements, a variety of improvement alternatives should be evaluated, in addition to roundabouts, to determine whether a roundabout is the most appropriate alternative.	Pennsylvania Guide to Roundabouts (70)
Rhode Island	KAI Database (10)	RI operated with an unofficial roundabouts-only policy based on an email to the list serve about a year ago.	Roundabout Listserv (38)
South Carolina	KAI Database (10)	NA	NA
South Dakota	Roundabout Listserv (38)	NA	NA
Tennessee	KAI Database (10)	Inferred	Instructional Bulletin No. 10-07 (71)
Texas	KAI Database (10)	Research in Progress	Transportation Research Board: Research in Progress (72)
Utah	Roundabout Listserv (38)	Inferred	Developing Guidelines for Roundabouts (73)
Vermont	Roundabout Listserv (38)	Vermont was first in nation with State legislation (still in effect) in 2002 requiring the State transportation dept. to use roundabouts at dangerous intersections. (Vermont Laws, Act 141, Sec. 31).	Roundabout Listserv (38)
Virginia	Roundabout Listserv (38)	VDOT recognizes that Roundabouts are frequently able to address the above safety and operational objectives better than other types of intersections in both urban and rural environments and on high-speed and low-speed highways. Therefore, it is VDOT policy that Roundabouts be considered when a project includes reconstructing or constructing new intersection(s), signalized or unsignalized. The Engineer shall provide an analysis of each intersection to determine if a Roundabout is a feasible alternative based on site constraints, including right of way, environmental factors and other design constraints. The advantages and disadvantages of constructing a Roundabout shall be documented for each intersection. When the analysis shows that a Roundabout is a feasible alternative, it should be considered the Department's preferred alternative due to the proven substantial safety and operational benefits.	Road Design Manual (74)
Washington	Roundabout Listserv (38)	Prior to proceeding with the design, provide an analysis of alternatives for a proposal to install a traffic signal or a roundabout on a state route, either NHS or Non-NHS, with a posted speed limit of 45 mph or higher, approved by the region Traffic Engineer, with review and comment by the HQ Design Office.	Design Manual (75)
West Virginia	KAI Database (10)	NA	NA
Wisconsin	Roundabout Listserv (38)	If an intersection warrants a signal or a four-way stop within the design life of the proposed project, the modern roundabout shall be evaluated as an equal alternative. Where there is an existing four-way stop or signal and there are operational problems with the current control, then the roundabout shall be considered as a viable alternative. As stated above the roundabout may be a viable alternative for a two-way stop control in certain circumstances. In either case, roundabouts are a potential intersection control strategy until such time that the evaluation indicates that the roundabout alternative is not appropriate.	Roundabout Guide (76)
Wyoming	Roundabout Listserv (38)	NA	NA

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