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# Hot spot analysis of the crash locations at the roundabouts through the application of GIS

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**Abstract.** Intersection safety is a critical issue as it accounts high percent of the total fatal and injury crashes combined. One of the safe alternatives is to convert the typical intersections into roundabouts to enhance the capacity and reduce crashes. Despite the advantages in the roundabout geometric design, there is a clear gap in understanding the relationship among crash types, injury severity, and roundabout configurations. As such, this research used five years (2011 to 2015) of traffic crash data collected from Oregon's Department of Transportation (ODOT). In this study, the Geographic information system tool (GIS) and the incident analysis tools have been used to identify hazardous location occurrence areas, hot spots, and factors that lead to roundabout accidents and decide how, when, and where accident countermeasures can be performed. The results indicated many cities with high crashes are not considered a hot spot area and the reverse. Besides, more driver injury crashes when the driver enters the roundabout at an angle, and more crashes are in four legs roundabout and three legs roundabout types. Several factors lead to roundabout crashes resulting in an injury, like drivers who did not yield right of way is the dominant crash, an improper change of traffic lanes, and followed too closely. Female drivers have more likelihood to involve in roundabout crashes than male drivers. With these findings, the current study would be useful for safety practitioners to select effective safety measures to avoid and minimize the incidence of accidents at the highest crash site.

## 1. Introduction

Although the enhancement of traffic safety is the primary concern of the highway agencies, traffic crashes have been increasing rapidly in recent decades, this due to many factors, including a sharp increase in vehicles using road networks, driver behavior, road condition, weather, and many other external factors [1]. According to the USA National Highway Transportation Safety Administration (NHTSA), the annual deaths due to traffic crashes were about 10-15 cases per 100000 population. Intersection safety is a critical issue as it accounts for 50 percent of the total fatal and injury crashes combined [2]. About one out of every four fatal accidents at or near an intersection [3]. Several intersections have been turned into roundabouts to increase capacity and avoid collisions [4]. Roundabouts have been increased in the U.S. from less than 100 in 1997 to about 1000 in 2007 [4]. In Oregon, roundabout construction has increased as replacements for signalized or STOP-controlled intersections. Some of the most beneficial aspects of the roundabout are reducing the speed limit and the number of points of dispute between road users [5].



The activity administered by the yield-at-entry run the show and the moderately lesser of geometric plan measures that intentioned connected to drive vehicular directions at roundabouts into a contract space. Worldwide ponders of intersections changed over to roundabouts demonstrate a consistent lessening in harm crashes, especially for crashes with a fatality or incapacitating injuries [6].

Based on previous research, roundabouts demonstrate a substantial increase in safety relative to the decreased overall number of accident accidents in minimizing severe crashes (fatal and crashes causing serious injuries). The results of property damage-only (PDO) accidents, however, are incredibly unpredictable. [7]. Despite the advantages of the roundabout geometric design its popularity in the United States including Oregon, there is still a need to clearly understand the relationship among crash types, injury severity, and roundabout configurations. Therefore, the current study's main objective is to discover some information needed by performing hot spot analysis using the Geographic Information System (GIS) to assist decision-makers in selecting effective countermeasures to avoid and minimize the frequency of crashes at the highest crash site.

## 2. Literature Review

One of the most effective methods for traffic accident research is spatial data and its analysis. Different terminologies have been used to describe road traffic crashes locations, hazardous road locations, high-risk locations, accident-prone locations, black spots, hot spots, hot zones, black zones, sites with promise and priority investigation locations[8][9]. The location of the highest incidence of an accident can be identified as a point or region where an incident has a persistent recurrence, and these locations are statistically determined. Different visual methods and reports on GIS in accident analysis have been established, including intersection analysis, segment analysis, cluster analysis, density analysis, pattern analysis, and modeling techniques for spatial accident analysis. GIS has been used in the transport sector since the 1990s [10] and can coordinate diverse types of data and maps that can be conveniently processed, exchanged, and manipulated.

[11] identified the epidemiology, hotspots, and modifiable risk factors involved within Baltimore's city from 2009 to 2013 to direct further geographic and epidemiological-based interventions. To classify clusters of injured pedestrians, [12] applied a spatiotemporal clustering technique and then explored the impact of personal and environmental influences on pedestrian injuries. To detect the roadway segments, where pedestrian accidents were substantially clustered, the Bernoulli model in SatScan was used. The possible temporal and spatial patterns of road crashes aggregated at the zonal traffic analysis (TAZ) level in urban environments have been identified by [13].

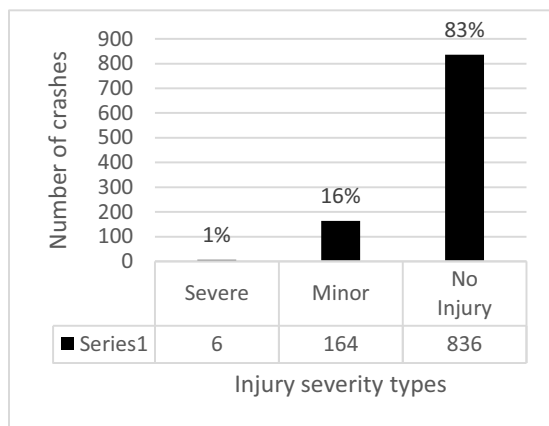
By using a geo-information approach, localization patterns and hotspot distribution were analyzed to determine the effect of spatial/temporal dimensions on the emergence of such patterns. Besides, [14] used the combination of geo-information technology and spatial-statistical analysis to analyze four clustering studies to better understand the patterns of traffic crashes in complex urban networks in Iran in order to highlight the role of spatial factors in their creation. Therefore, traffic accidents have become more frequent, and there are multiple tools for detecting dangerous areas of occurrence. In terms of shape, size, and position, various techniques create various hot spots. So, by conducting research and taking steps, it is an urgent job to eliminate these crashes. This research aims to build a GIS-supported framework utilizing the ArcGIS pro incident analysis tool. to identify hot spots and contributing factors that lead to roundabout crashes to help the decision makers to decide how, when, and where accident's countermeasures can be performed to diminish the crash rate severity.

## 3. Site and Data Description

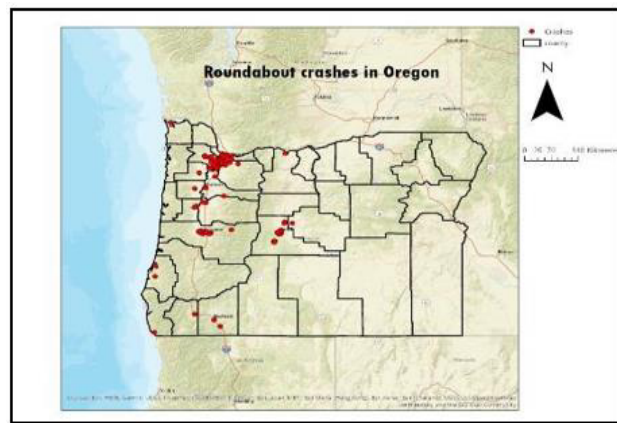
It is generally accepted that the number of crashes at roundabouts are fewer than those at signalized intersections. Note that the key factors that lead to crash injury forms can be captured by detailed crash data is more complicated concerning the appropriate number of observations that correctly characterizes the population. As such, this study collected traffic accident data from the Oregon Department of Transportation

(ODOT) Crash Monitoring and Reporting Unit for five years (2011 to 2015). The data acquired reveals that 1,006 roundabout crashes have arisen (shown in Figure 1 and Figure 2).

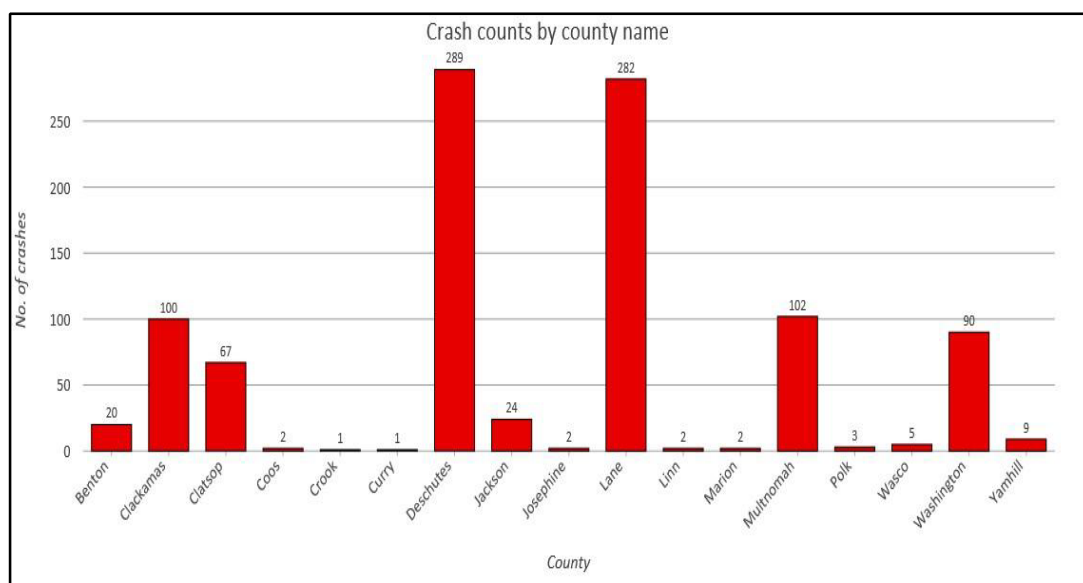
In seventeen counties, these crashes occurred at various types of roundabouts, as shown in Figure 3. Deschutes and Lane counties have the largest number of accidents, with 289 and 282, respectively. Figure 4 illustrates the crash distribution within Deschutes county, and it can be noticed that there are three clustering at the center of the county. Most of the crashes are at four and three legs roundabouts, as shown in Figure 5, with 241 and 47 crashes, respectively. With the same pattern, Figure 6 that most of the roundabout crashes at Lane county have clustered in the center of the county with different types of roundabout configurations. Figure 7 presents the number of crashes by roundabout configuration in Lane county, and it is shown that most of the crashes are at the four-leg roundabout with 242 crashes following 18 crashes at three leg roundabouts with 17 and 5 crashes at five-leg and other unknown different types respectively.



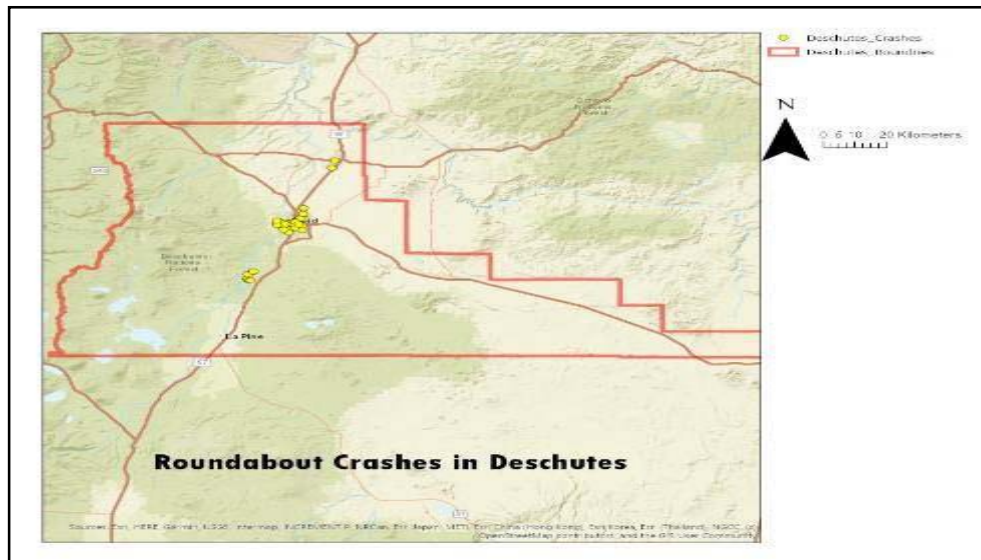
**Figure 1.** Driver injury severity types at roundabouts in Oregon from 2011-2015.



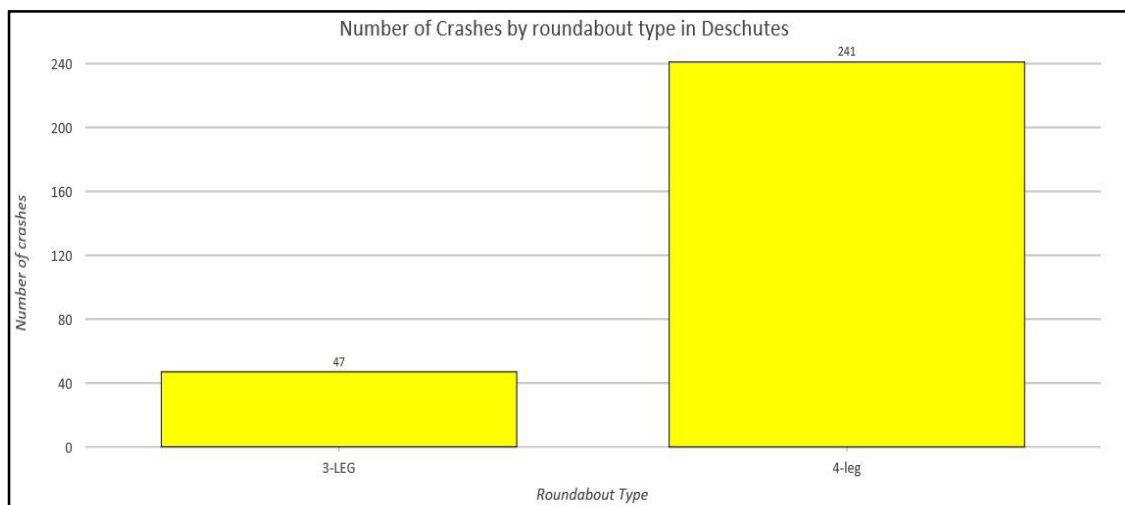
**Figure 2.** Roundabout crashes in Oregon



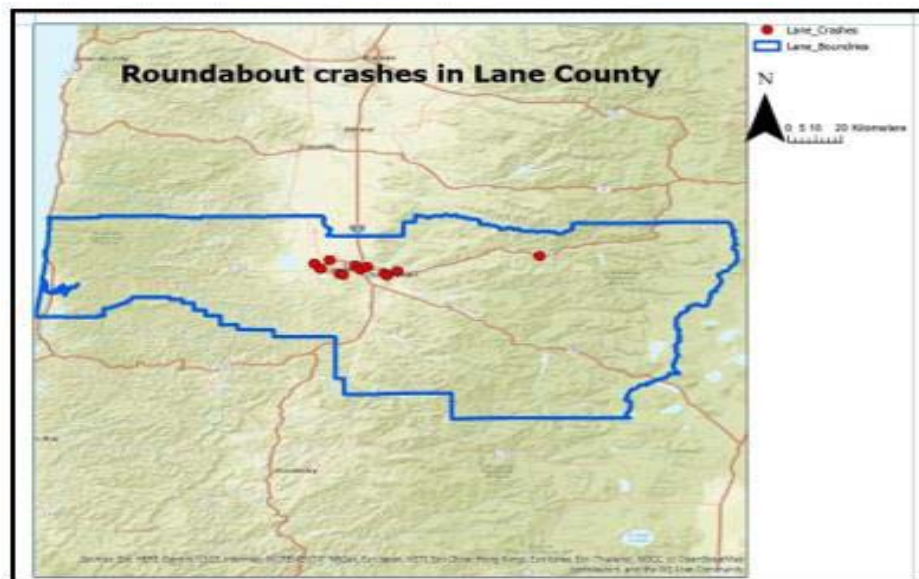
**Figure 3.** Number of crashes by county name



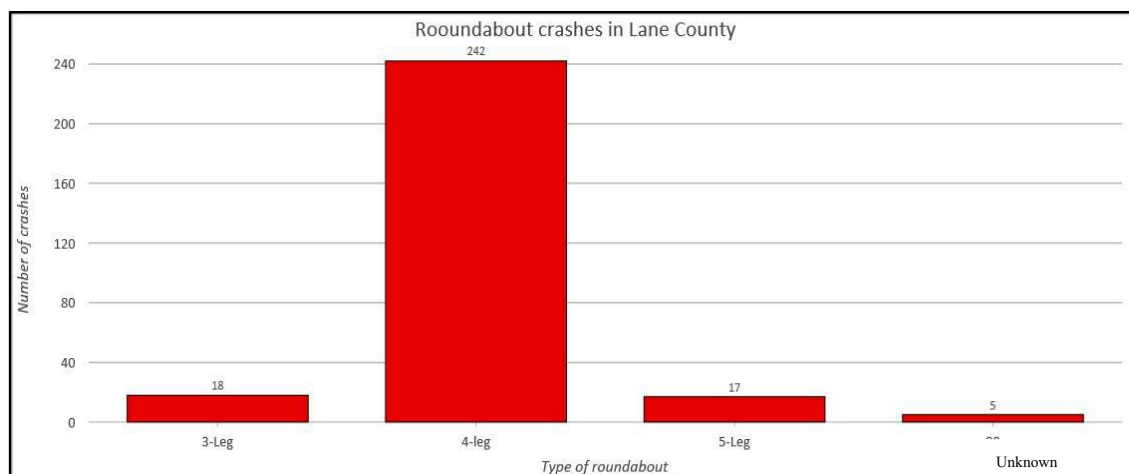
**Figure 4.** Roundabout crashes in Deschutes County



**Figure 5.** Number of crashes by roundabout configuration in Deschutes County



**Figure 6.** Roundabout crashes in Lane County



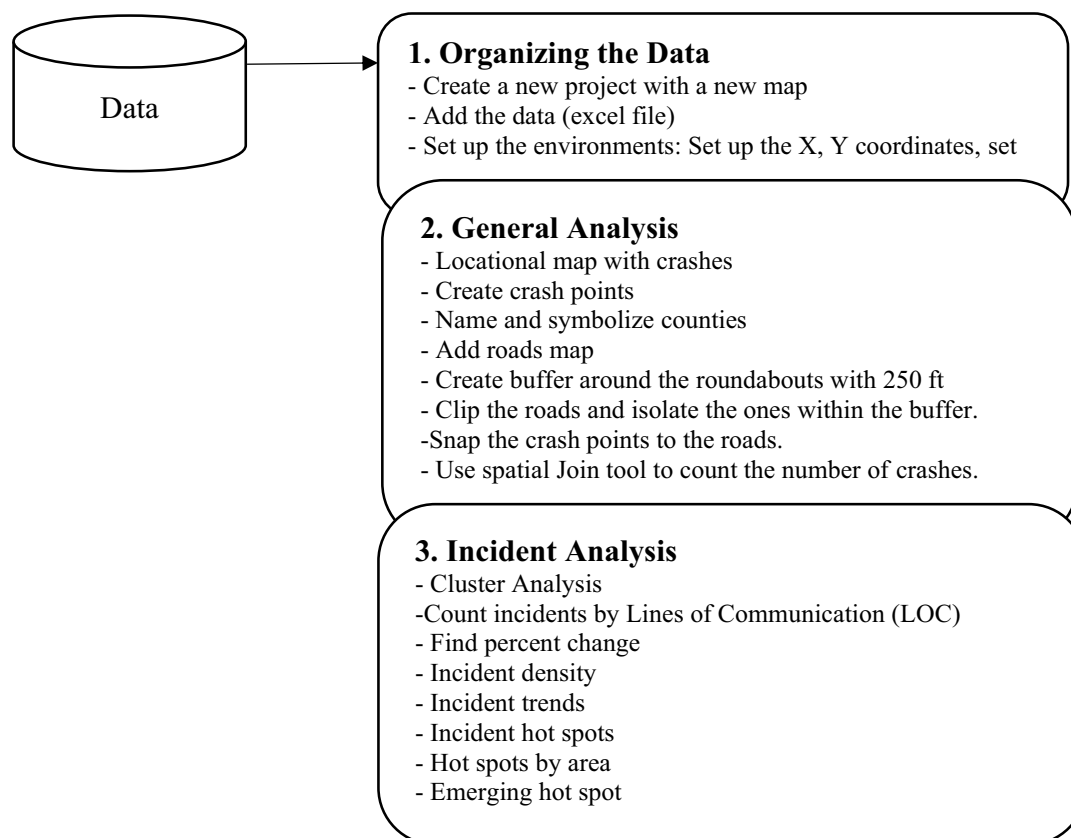
**Figure 7.** Number of crashes by roundabout configuration in Lane County

#### 4. Methodology

This study aims to understand the peculiar existence of crashes involving driver injury severity at Oregon roundabouts from 2011 to 2015 with 1006 crashes in various counties with different types of roundabout configurations with two outcomes results (no injury and injury). These results reflect the mixture of no driver injury and other types of injuries under injury outcomes. In contrast to collisions that result in accidents, this is achieved because of the large amount of no injury crashes. Accordingly, the category of combined injury involves fatal, severe, and minor injury results, whereas only no injury results are included in the category of no injury. This combination aims to raise the number of observations when statistical methods are introduced to minimize the uncertainty induced by random effects [15]–[17].

To determine the geospatial distribution of traffic crashes and areas with higher incidence densities, geospatial data was analyzed by using ArcGIS pro 2.6. The spatial clustering of crashes and hotspots was

analyzed using the Getis-Ord Gi\* method of spatial autocorrelation and incident analysis using the Incident Analysis Tool containing maps and software that can be used to conduct outline and tendency analysis. Figure 8 offers a detailed flowchart showing the overall geospatial analysis and the technique of incident analysis.



**Figure 8.** Geospatial incident analysis methodology

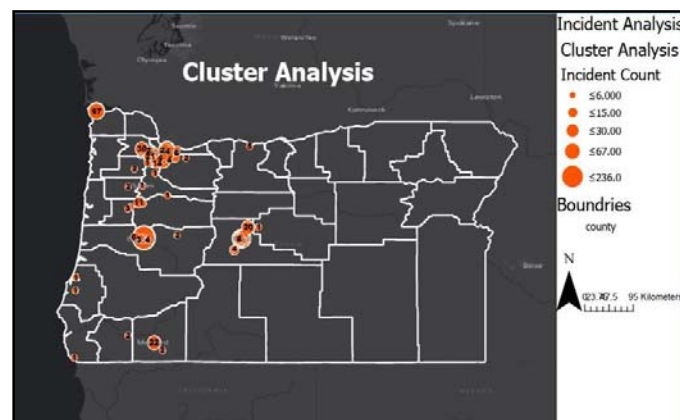
## 5. Results and discussion

With the GIS application and the incident analysis tools on the roundabout crashes, there are many cities with high number of crashes not considered a hot spot and the reverse. In this part, the primary analysis tool will be discussed briefly, as described below.

### 5.1 Cluster analysis

The research team used ArcGIS cluster analysis tool to determine the clusters. This tool can identify incidents within certain cluster distances (i.e., by measuring x, y tolerance) to snap the locations together. By combining these co-occurring points with the total count number, a value is measured to hold the sum of all incidents within each cluster. Figure 9 shows the results of the cluster analysis with different incident counts over all of Oregon.

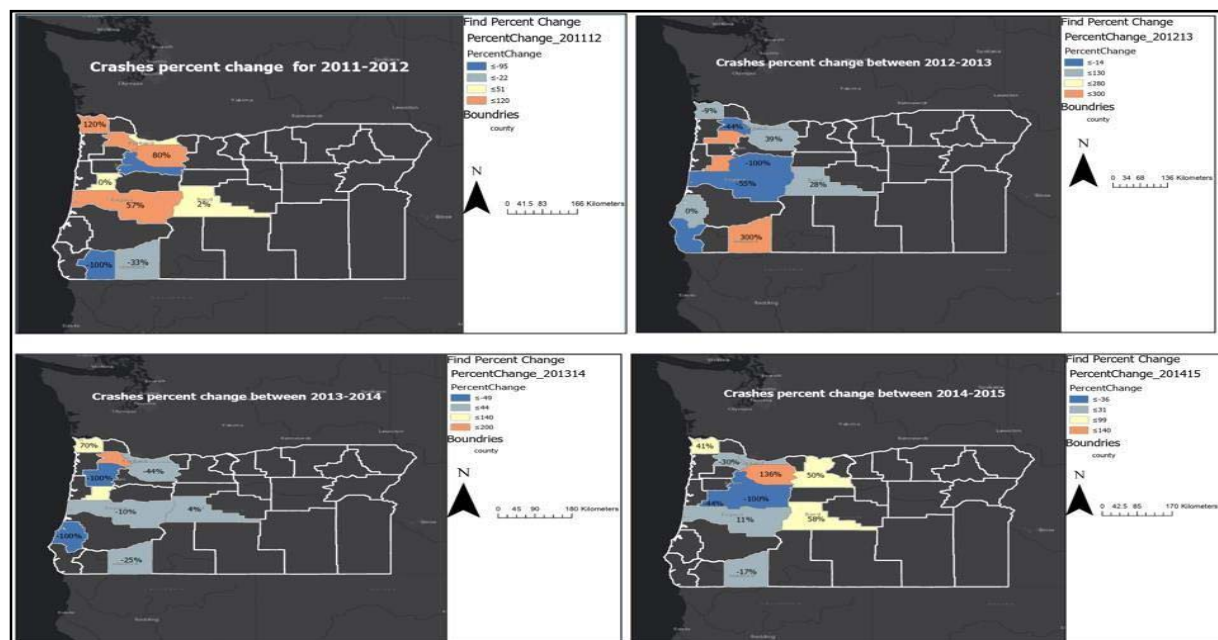




**Figure 9.** Crashes Cluster analyses

### 5.2 Percent change calculation

This instrument calculates the number of occasions in one, two, a few, or all categories in an indicated time run, and inside one or more ranges of intrigue, compared to the number of episodes in those same categories in a past period. It computes patterns for any time outline, such as weeks, months, seasons, or a long time. Slant computation requires two numbers speaking to the two comparable time outlines. Ancient movement speaks to the occurrence volume for the primary (prior) period of comparison, and modern action speaks to the comparing occurrence volume for the moment (afterward) period of comparison. The slant is computed by subtracting the number of ancient episodes from the modern episodes, partitioning the contrast by the ancient, and at last, increasing the remainder by 100. Figure 10 illustrates the crash percent changes for the case study during the specified time. Different increasing and decreasing crash percentage occurred between 2011 to 2015.



**Figure 10.** Crashes percent changes from 2011 to 2015



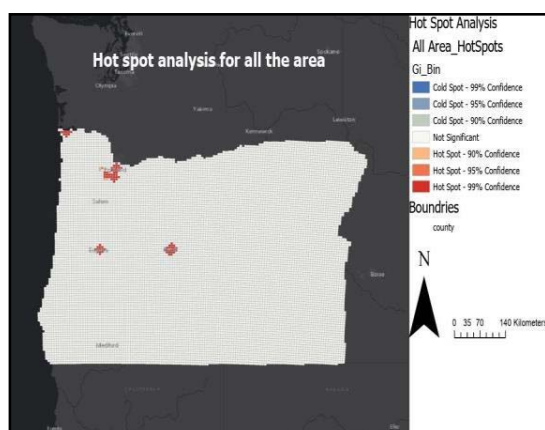
### 5.3 Hot spot analysis

#### 5.3.1. Hot Spots by Area

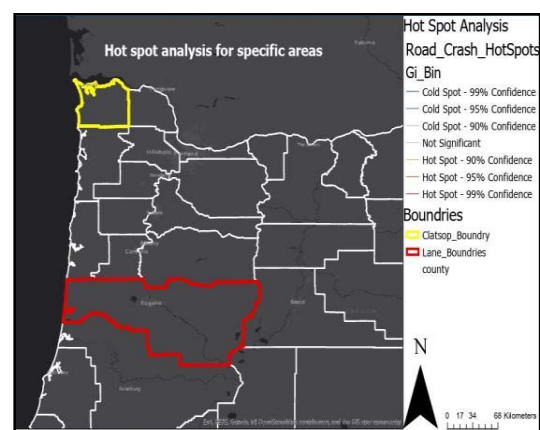
The Hot Spots by Zone apparatus recognizes elevated concentrations of episodes in each intrigue zone instead of considering regions as an entirety. This sort of examination uncovers unobtrusive designs and underpins the course of endeavors inside a characterized range of duty. It runs a hot spot examination for each range within the input region of intrigued Highlights. Figure 11 illustrates the hot spot areas for roundabout crashes and the results identified four hot spots in Oregon.

#### 5.3.2. Incident Hot Spots

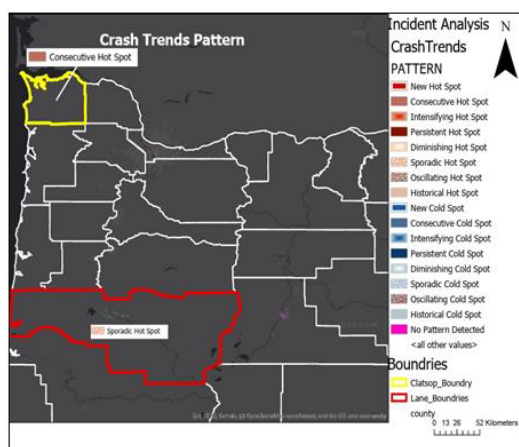
Figure 12 appears regions of negative centrality (cold spots), no significant, and positive importance (hot spots) employing a blue to-red color plot for the incident by their exact locations. The results indicate that there are just two counties with hot spot locations: Lane County with a red boundary and Clatsop County with a yellow boundary. The crash trends as Figure 13 shows indicate that there are sporadic hot spots in Lane county and consecutive hot spots in Clatsop county, whereas all the other locations have no detected pattern. Incident density has been illustrated in Figure 14.



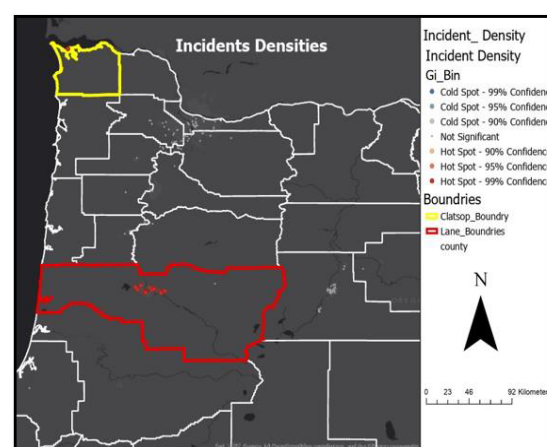
**Figure 11.** Hot spot area for roundabout crashes in Oregon



**Figure 12.** Hot spot locations in Lane and Clatsop boundaries



**Figure 13.** Crash trends pattern



**Figure 14.** Roundabout incident densities

## 6. Result Discussion

According to the roundabout geometric design, over 1006 crashes with different severity in Oregon between 2011 to 2015, more crashes are in four legs roundabout type, three legs roundabout type, and most crashes are in Lane and Deschutes counties, as shown previously in figures 5 and 7. The analysis mentioned before the Incident Analysis tool was used to analyze driver injury severity with two classes (no-injury and injury). The results indicate that with hot spot area analysis, there are different locations in different counties considered hot spots, as shown in Figure 11. With getting more in depth with our analysis with an incident hot spot, it can be noticed that there are just two counties with hot spot locations, which are Lane and Clatsop counties, despite that Deschutes county has much more crashes than both of them. To figure out this situation between the previously mentioned counties, more in-depth research has been conducted with these locations' datasets like the weather, daylight condition, gender. The research indicates that all the crashes in the three counties (Deschutes, Lane, and Clatsop) occurred during the daylight and in exact weather conditions, but with getting more in-depth research, it found that the following interesting differences between them could be a possible explanation of the hot spot categorization results.

### 6.1. Incident Clustering

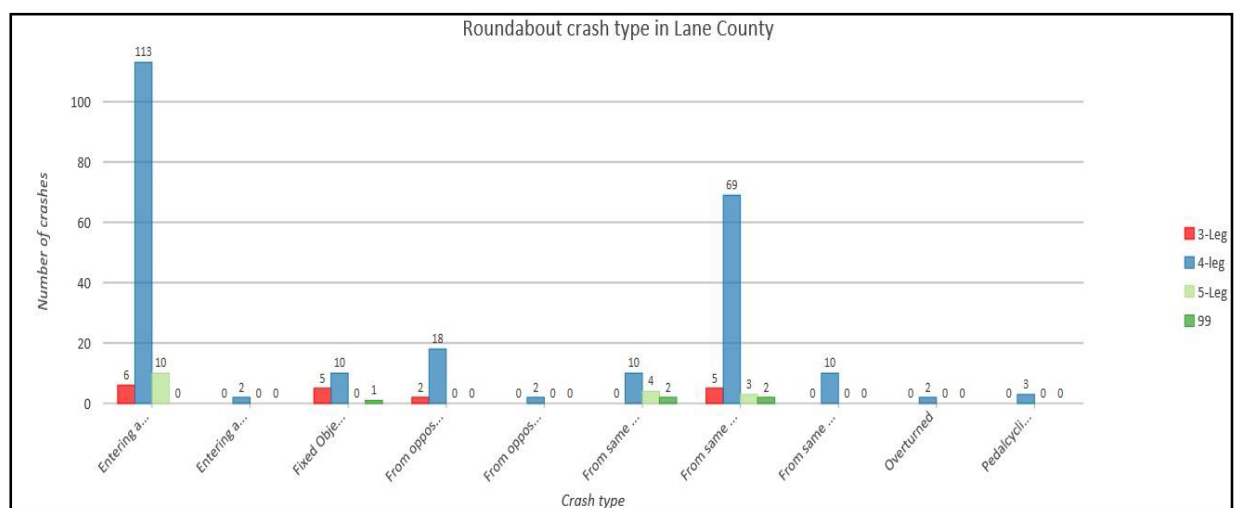
The spatial analysis distinguishes clusters with high and low highlight trait values within the consider zone, and with the remove that gives maximized spatial autocorrelation over the ponder zone, clustering designs of highlights are most discernible and obvious [18]. The incident analysis solution shows a specific clustering in the roundabout crashes that may consider some areas as a hot spot and so the reverse. Figure 15 provides detailed visual representations of the crash clusters in the area, and it can be noticed that despite Lane county having the highest number of crashes, it does not consider a hot spot location because the crashes are distributed among eighteen roundabouts with fifty-one crash clusters at one location. Simultaneously, Lane county's crashes have distributed among ten roundabouts and with 236 crash clusters in one location, which make this area a significant hot spot location. According to Clatsop county, as shown in Figure 15, sixty-seven crashes clustered in one location also make this area a hot spot location.



**Figure 15.** Roundabout incident counts

### 6.2. Crash characteristics

In terms of crash characteristics like the crash types and the causes of these crashes, different vital components were found to impact the level of crash seriousness at roundabouts. Three dominant crash types are identified as shown in Figure 15: entering at an angle, crash from the same directions, and crash from opposite directions in both Lane and Clatsop counties. The results show more severe crashes when the driver enters the roundabout at an angle with 113 and 25 crashes, as shown in figures 15 and 16, respectively, no matter the type of the roundabout configuration in both counties. Two significant crashes caused by the driver were found in Lane county's roundabout, as shown in figure 17 and: did not yield right of way and followed too closely with 110 and 26 crashes. A driver drawing closer to a roundabout must moderate down or halt for vehicles halted ahead and yield to activity within the roundabout. Also, it is crucial to reduce speed with a proper distance from the vehicle ahead when approaching a traffic circle and while in it and if a driver is speeding, the driver may not have sufficient time to slow down when entering the roundabout, failing to do so will result in a collision. In Clatsop County (Figure 19), the results show did not yield right of way is also the dominant crash cause with 43 crashes and nine crashes due to improper change of traffic lanes crashes. Drivers are supposed to use their turn signals to indicate that they are to exit from the inner lane. However, drivers might forget to use their signals, and it is exceptionally critical to watch the signs and bolts to decide which path to utilize some time recently entering an indirect roundabout because changing from the inside to the outside lane is illegal anywhere [19].



**Figure 16.** Type of crashes at the roundabout in Lane County

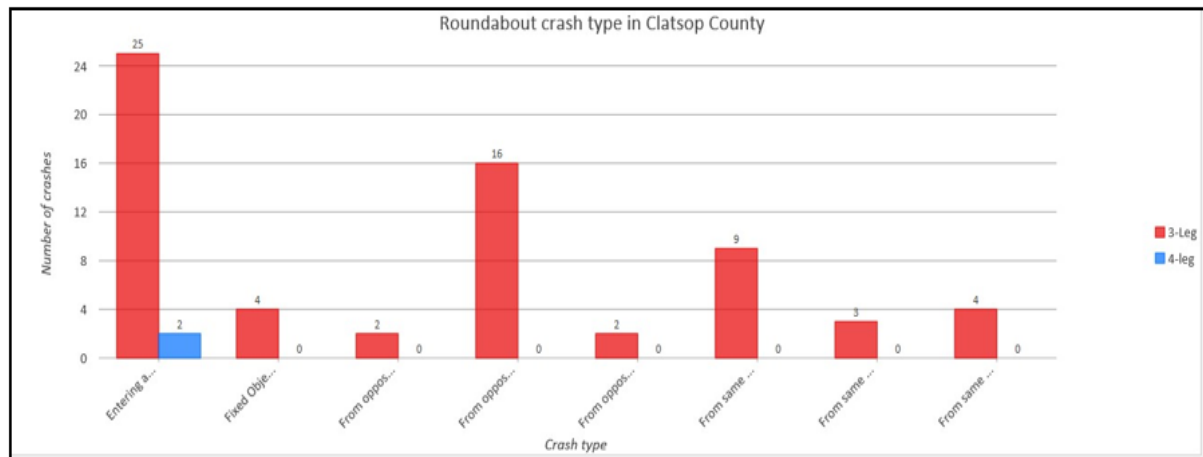


Figure 17. Type of crashes at the roundabout in Clatsop County

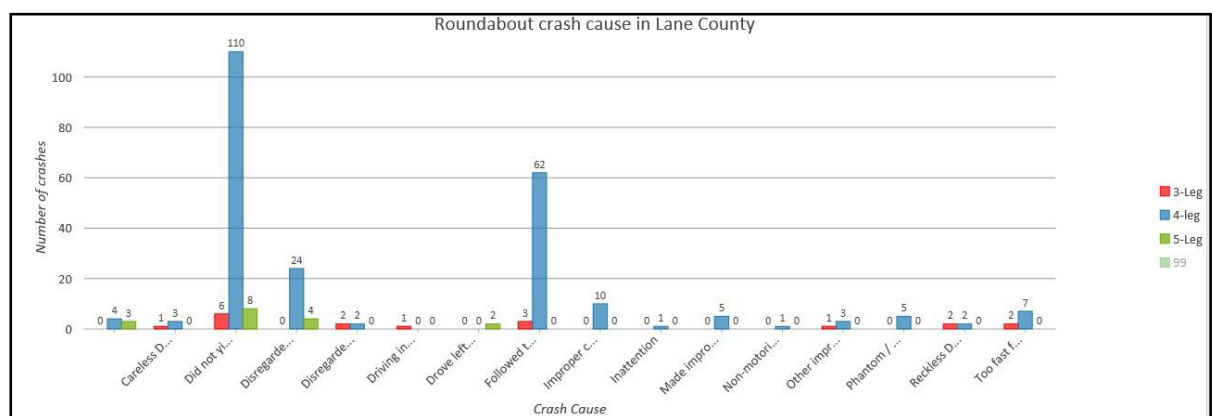


Figure 18. Cause of crashes at the roundabout in Lane County

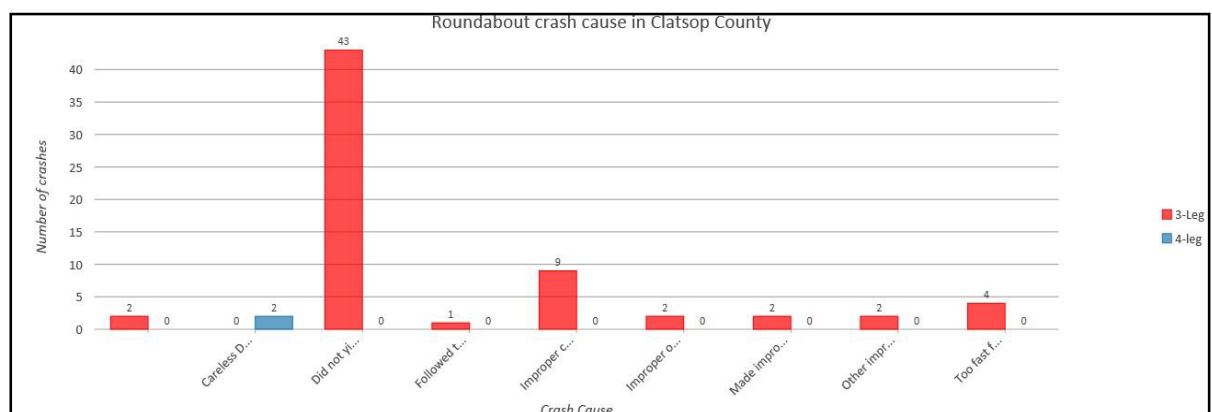
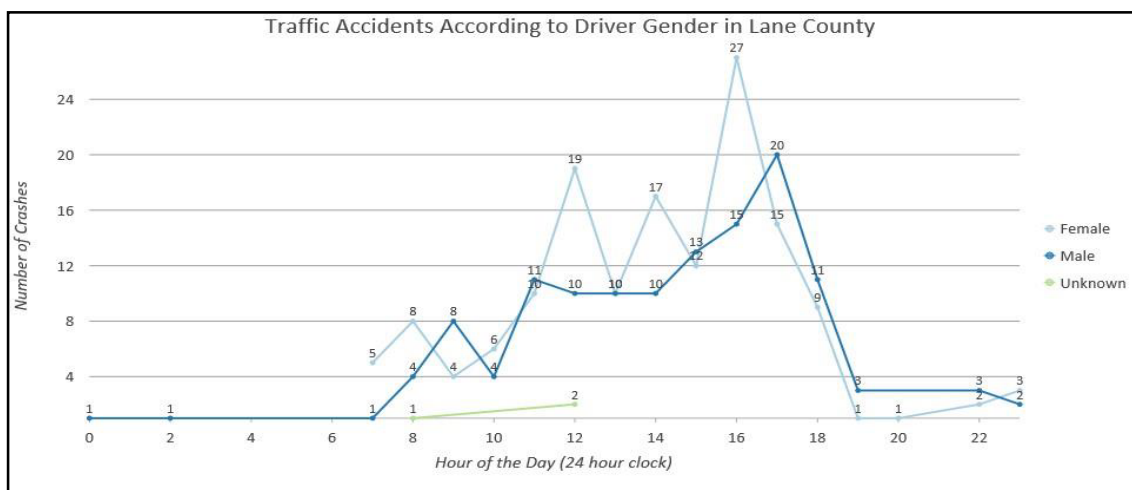


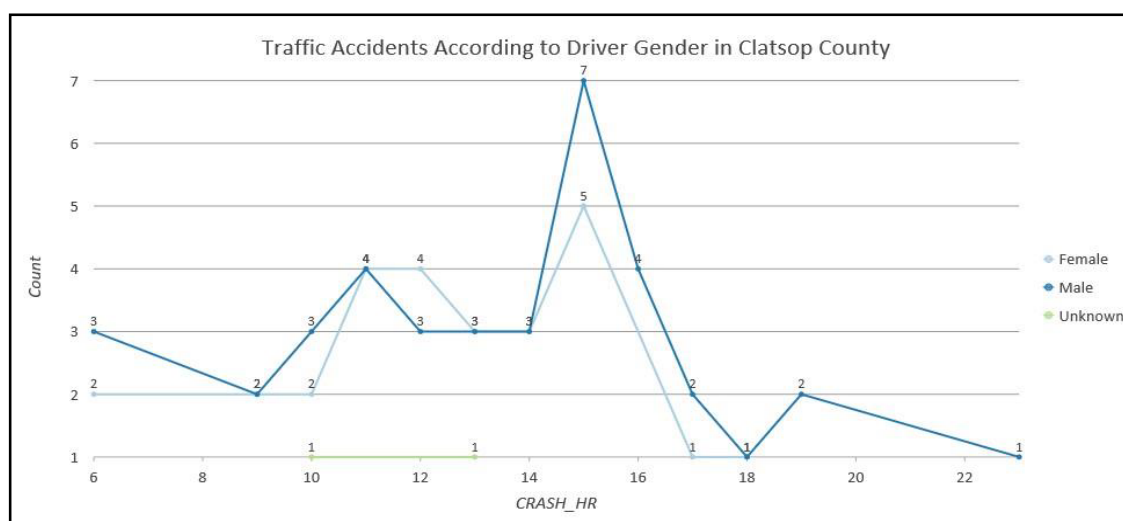
Figure 19. Cause of crashes at the roundabout in Clatsop County

### 6.3. Gender of the driver

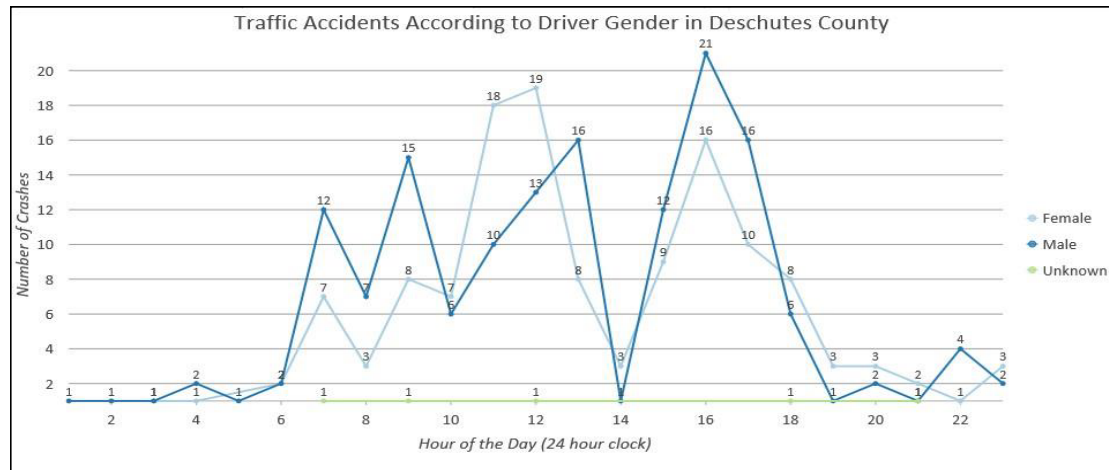
In general, the studies indicated that male drivers are less likely to include in harm crashes. This can be due to the physical contrasts than females. Research has found that females have a higher probability of getting injured than males in crashes with the same impact [20]. This study found that female drivers are more likely to be involved in roundabout crashes and get injured with 27 crashes, as shown in Figure 20 in Lane county, whereas male drivers are involved with 20 crashes. Moreover, it can be noticed that there are some peak crash hours for a female driver between 12 pm-6 pm on the other had the highest peak for the male drivers in between 4-6 pm. Clatsop county has a smaller number of male and female drivers, as shown in figure 21 with 7 and 5 crashes for female and male drivers. Interestingly male drivers have almost the same crash at a peak time of period between 2-4 pm and the female drivers. Additionally, Figure 22 presents the different peaks time for both male and female drivers, and it is clear that female drivers dominate most of the crashes with a more extended time during the day.



**Figure 20.** Roundabout crashes by driver gender in Lane County



**Figure 21.** Roundabout crashes by driver gender in Clatsop County



**Figure 22.** Roundabout crashes by driver gender in Deschutes County

## 7. Summary and Conclusion

Roundabouts demonstrate a substantial increase in safety relative to a decrease in the overall number of accident accidents in minimizing severe crashes, but the results of property damage-only accidents, however, are incredibly unpredictable. This study aims to identify and analyze dominant crash types and locate the hot spot areas for roundabouts in Oregon by considering detailed information on the crash location for five years (2011 to 2015) with 1,006 crashes. The current study performed hot spot analysis using the Geographic Information System (GIS) and the incident analysis tool.

The results show evidence that some areas have the highest number of crashes, but it does not consider a hot spot location. Both Lane and Clatsop counties are considered a hot spot location for roundabout crashes, and there are more injury severity crashes when the driver enters the roundabout at an angle. The results output indicates that more crashes are in four legs roundabout and three legs roundabout types, and several factors lead to roundabout crashes that result in an injury. For example, drivers who did not yield the right of way are also the dominant crash cause an improper change of traffic lanes and followed too closely. Female drivers are more likely to be involved in roundabout crashes and getting injured than male drivers, and most crashes occurred during daylight and in clear weather conditions. The current study delivers convenient intuitions for a better thought of the features that led to getting injured or not in crashes with specifying the hot spot areas at roundabouts through the GIS application.

In future work, extra crash specific factors are prescribed to examine roundabout damage seriousness, such as the particular area of the crash or extra geometric plan subtle elements. In doing so, an injury severity picture with the next determination can be gotten, which can offer more understanding of the plan related variables that lead to extreme crashes at roundabouts. In summary, it is hoped that utilizing the incident analysis tool in the current work will help those concerned about the roundabout characteristics and the crashes related to this to get a better understanding of the variables and the better ways that should be taken into account to diminish the property damage only crashes at roundabouts.

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