A Study on the Analysis of Law Violation Data for the Creation of Autonomous Vehicle Traffic Flow Evaluation Indicators

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Abstract

The study analyzes the reason for the steady increase in the number of traffic accidents in Yongin City, Gyeonggi-do, despite the improvement of Korea's traffic accident system and the decrease in the number of traffic accidents. Seven years of traffic accident data is collected to analyze major legal violations and accident risks and to derive accident-prone areas and road risk indices through QGIS mapping. Based on this analysis, it identifies the causes of accidents in multiple accident areas, proposes improvement measures like the installation of a median strip and an unmanned traffic control device near a crosswalk, and emphasizes the significance of driver awareness and safety education. The aim of the study is to analyze road risk factors and suggest improvement measures to prevent traffic accidents, with the goal of improving the traffic situation in Yongin city.

Keywords: Traffic Accident, Accident Analysis, Prevent, Roadway.

1 Introduction

Recently, Korea's traffic safety system has been steadily improving, and the number of traffic accidents has been gradually decreasing, with 232,035 in 2015, 217,148 in 2018, and 203,130 in 2021, according to statistics from the National Police Agency. On the other hand, according to the TAAS traffic accident analysis system of the Korea Expressway Administration, the number of traffic accidents In Yongin, Gyeonggi-do was 3,132 in 2015, 3,205 in 2018, and 3,603 in 2021, showing a steady increase in the

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number of traffic accidents in the Yong in an area. Therefore, this study collected data specifically on traffic accidents in Yongin over a period of approximately seven years, spanning from 2015 to 2021. In particular, we derive the main violations of laws and regulations from the collected traffic accident data and focus on Article 5 (violation of signals or instructions), Article 25 (violation of intersection passage method), and Article 48 (violation of safe driving duty), which have the highest frequency of violations. The GIS was used to map the location information of the accident and analyze the cluster area's vulnerability. The road risk index was derived by analyzing data including intersection shape and weather information, leading to the creation of a matrix. Our aim, through the results of this study, is to identify the causes of the increase in traffic accidents (Udayakumar, R., 2023). Additionally, we aim to enhance the traffic situation in Yongin and contribute to the prevention of such accidents through accident analysis.

2 Related Work

Prior Work

The paper titled "Development and Utilization of Traffic Safety Prediction Index Linked to Weather Information" (2015) addressed the limitations of current traffic accident prediction models, which are restricted to specific points and objectives. This study developed a traffic safety forecast by utilizing weather information provided by the Korea Meteorological Administration. The objective is to provide a service that informs about the risks of accidents in advance. The concept of Equivalent Property Damage Only (EPDO) was utilized to establish Equivalent Casualty Loss Only (ECLO), which quantifies the severity level of casualties, in the development of a traffic accident risk assessment index. (Jo, J.H., 2014) (Jung, K.Y., 2017) (Namseon Kim, 2023) (National Legislation Clearinghouse Road Traffic Act) (Kim, 2023) (Mindu Choi, 2023) (Kim Yong-woo, 2023) (Jo, J.H., 2014) (Public Safety Policy Institute, 2022) (Hazardous Roadway Forecasting System) (Yoon, 2021) (Kwon, 2023)

In a 2017 study, the relative risk of accidents occurring at major intersections on Busan's main roads was determined by analyzing traffic accident data. This calculation determined the risk by combining geometric structure data of intersections with dynamic data such as driving hours, using conditional probability. Furthermore, based on the results obtained by applying ECLO, the study classified the accident types, provided customized accident forecasts, and offered tailored information to drivers.

In a 2017 study conducted in Busan, researchers combined geometric structure data of major intersections with dynamic data, such as driving hours, to analyze traffic accident data. The researchers used conditional probability to determine the relative risk of accidents occurring. Furthermore, by implementing ECLO, the study not only classifies different accident types but also offers tailored accident forecasts and personalized information to drivers.

This study utilizes seven years of annual traffic accident data acquired from the Yongin West Police Station in the Yongin area, in line with the previously mentioned studies. This study utilizes Yongin traffic accident data to identify noteworthy violations of the Road Traffic Act. By utilizing QGIS mapping, it performs a frequency analysis on each provision and suggests preventive measures for areas prone to accidents. Additionally, the frequency analysis results are utilized for calculating a road risk index.

Traffic Accident Risk Analysis

By utilizing traffic accident data and QGIS mapping, we analyze the frequency and risk factors that cause major violations of the Road Traffic Act in Yongin, Gyeonggi-do. In particular, the causes of traffic accidents are analyzed by examining the relationship between specific areas of terrain characteristics and intersection distribution. By analyzing this data, we can gain insights into the unique characteristics of each region and develop customized traffic accident prevention measures for each area.

- **Legal Violations and Traffic Accidents**

In the seven years of traffic accidents from 2015 to 2021, the most frequently violated sections of the law were Article 5 (violation of signals or instructions), Article 25 (violation of the method of passing through an intersection), and Article 48 (1) (violation of the duty to drive safely). Article 5, Violation of Signals or Instructions, states that pedestrians and drivers traveling on a roadway must obey signals or instructions displayed by traffic safety facilities and signals and instructions given by police officers.

Article 25, Intersection Procedure Violations, states that drivers of all vehicles must drive right and left when making a right turn, and how to drive at intersections.

Article 48 (1) Violation of the Duty of Safe Driving states that every vehicle or driver shall accurately operate the steering, braking and other devices of the vehicle, and shall not drive at a speed or in a manner that causes danger and obstruction to other persons in accordance with the structure and performance of the vehicle.

Compared to the national traffic accidents, statistics from the National Police Agency show that violations of safe driving obligations accounted for more than 50% of the violations from 2007, when statistics began, to 2022, the most recent year for which statistics are available.

In addition, failure to signal or direct accounts for about 11% of the violations, along with failure to maintain a safe distance.

Table 1 shows the number of violations by year for each of the applicable provisions.

Table 1: Number of Violations by Year

Number Article	**`15**	**`16**	**`17**	**`18**	**`19**	**`20**	**`21**
Article 5	115	135	113	124	142	137	123
Article 25	81	72	70	53	80	103	112
Article 48	595	556	545	556	514	562	656

The traffic accident statistics for Yong in also show that violation of the duty of safe driving and violation of signals or instructions are the most violated legal provisions in the traffic accident statistics.

- **Direction Estimation of Traffic Accidents**

The direction of the accident location was not included in this paper. However, the following inverse trigonometric function is used to calculate the direction associated with the accident's occurrence. The arctan function calculates the angle using the slope values of the ||x|| and ||y|| coordinates. It is impossible to distinguish between the directions of Northbound and Southbound. Therefore, we use the arctan2 function, the inverse function of tan, $-\pi \sim \pi$ to accurately determine which quadrant the angle belongs to and provide the angle in the range. The angle θ between the two points is defined as follows:

In Equation (1), The distances between the latitudes and longitudes of the two points, ||x|| and ||y||, are calculated as follows

$$||x|| = xdst - xacc$$
$$||y|| = ydst - yacc \quad (1)$$

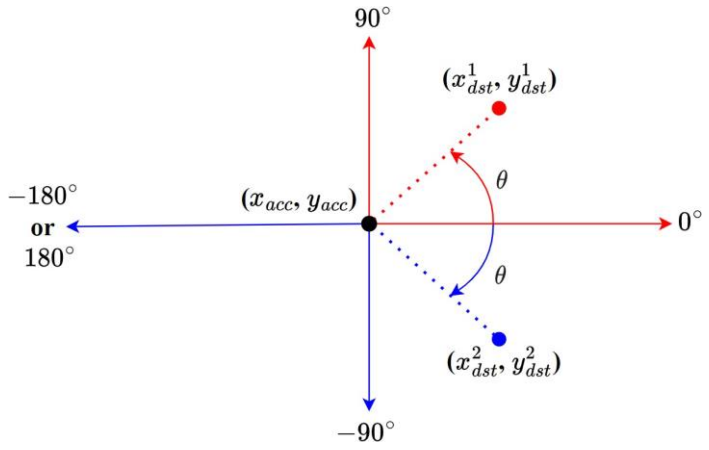

Figure 1: The Distinction Between up and Down According to the Degree

$$\text{Direction} = \begin{cases} N, & 0 \le \theta < 180 \\ S, & -180 \le \theta < 0 \end{cases} \quad (2)$$

In Equation (2), If θ is between 0 and 180, it is the Northbound; if it is between −180 and 0, it is the Southbound. Thus, Figure 1 show the direction is Northbound for (xacc, yacc) and (x1dst, y1dst) in the first quadrant because their relative position is (+,+) and for (x1dst, y1dst) in the second quadrant because their relative position is (−,+). On the other hand, the direction is Southbound for (x2dst, y2dst) in the fourth quadrant because its relative position to (xacc, yacc) is (+,−). Finally, for (x1dst, y1dst) in the third quadrant, the relative position is (−,−), so the direction is Southbound. (Cho, M., 2023)

- **Road Traffic Act Chapter 13 Penalties and Accident Prevention**

In Korea, the Road Traffic Act imposes penalties on individuals who violate traffic laws, and anyone utilizing the roads may face punishment through fines, imprisonment, or detention. The nature of the penalty determines the specific consequences, and in certain situations, fines may be combined with detention. Chapter 13 of the Road Traffic Act specifies the penalties for violators of traffic laws, as well as the targets and punishment provisions. This enables the imposition of penalties in case of a traffic accident. However, this is merely a reactive measure; therefore, there exist alternatives to proactively prevent traffic accidents from occurring in the first place. The Korean Eye Foundation distributed transparent umbrellas for children's traffic safety as part of their pedestrian safety education program. In addition, the Sichuan Police Department found that elderly people over the age of 60 accounted for 37.5% of all pedestrian fatalities in traffic. The Korea Expressway Administration will conduct customized traffic safety education sessions for elderly drivers as part of driver safety education. As shown in Table 1, the high percentage of violations of safe driving obligations and violations of signals or instructions in the total traffic accident citations is not only a result of Yongin City, but also a violation that applies to national traffic accident statistics. Therefore, safety education is especially expected to be necessary for drivers. (Ji, 2010) (Kim, 2017) (Dohoon Kim, 2011) (Yang, 2023) (Gun-An Kwon, 2019) (Kim, 2020) (Jung, 2015) (Ministry of the Interior, 2023) (Dong Hyun Lee, 2022) (Lim, 2014) (Lee, 2019) (Bao, J., 2018)

3 Analyze Traffic Data

QGIS and Risk Classification

QGIS is software for geographic information systems that utilizes spatial data for analyzing, viewing, editing, and various other functionalities. This is especially valuable when dealing with data that includes location information, such as traffic accident data. You can also map geographic data to create, edit, visualize, and analyze areas prone to accidents, road hazards, and more.

QGIS is an effective software for analyzing and visualizing geographic data, including traffic accident data, and it significantly contributes to the prevention of traffic accidents.

We utilized this software to convert the accident locations in the Yongin dataset into latitude and longitude coordinates. Then, we used QGIS to map them and analyze areas with multiple accidents.

The results of mapping the traffic accidents that occurred in Yongin City from 2015 to 2021, which violate the most legal provisions related to traffic, using QGIS, are presented in Figure 1. The figure depicts violations of Article 5 (traffic signal instructions), Article 25 (intersection passage method), and Article 48, Paragraph 1 (safe driving).

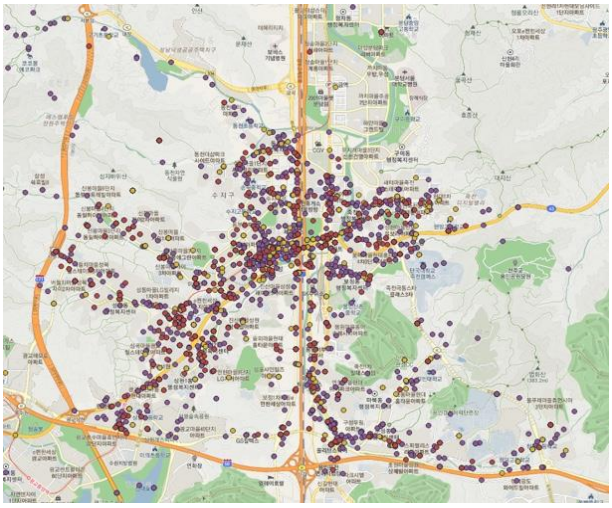

Figure 2: QGIS Mapping(1)

As a result of analyzing the mapping results, it was found that traffic accidents occurred mainly in places with a high flow of people due to the high distribution of flat intersections and residential complexes such as intersections and three-way streets in Yongin. The results of mapping the intersections near the water district office station and the three major roads are shown in Figure 2. We observed that the intersection near Suji District Office Station had the highest percentage of accidents. Installing a median in this area, which has a high traffic volume and many lanes, could help lower the rate of traffic accidents. Installing median helps maintain safe traffic flow by dividing the road into two lanes in each direction. By physically blocking the lanes in both directions, it prevents both intersection collisions and head-on collisions. In addition, there should be active promotion of driver awareness and safety education. Many accidents, particularly those that involved a violation of Article 5 on the "violation of signals or instructions," were observed occurring near crosswalks. Installing unmanned traffic enforcement equipment can help to prevent accidents around crosswalks. The figure displays the outcome of mapping Poeun-daero and Yonggu-daero, with a particular emphasis on the three major laws (3).

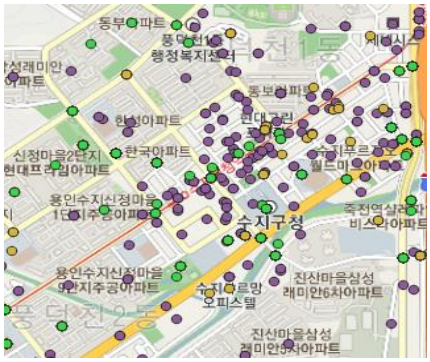

Figure 3: QGIS Mapping(2)

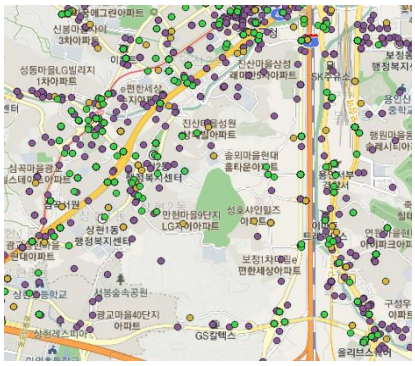

Figure 4: QGIS Mapping(3)

Accidents are particularly common along Yonggu-daero and Poeun-daero. In particular, the Yonggu-daero intersection lacks any devices other than gaze guiding rods. Therefore, efforts should be made to install colored road markers, enabling drivers to drive smoothly. Drivers can be guided to the correct driving route by installing colored markers on the road. They can choose the appropriate path by following these markers when performing driving actions, such as changing lanes, turning left, or turning right. In addition, colored guides can control the flow of traffic by prioritizing certain lanes or guiding drivers in the correct direction at merging or separating roads. Additionally, the vibrant colors on the road offer driver's visual cues that help them remain attentive, thereby allowing them to stay vigilant and prevent accidents caused by errors or lack of attention. Figure 4 shows the result of mapping Jukjeon 1-dong and Jukjeon 2-dong, with a focus on the three major laws. The area's high rate of traffic accidents is attributed to the large number of residents, which is due to the presence of apartment complexes, elementary, and middle schools

Figure 5: QGIS Mapping(4)

Due to the high number of pedestrians, the area around apartment complexes and schools experiences a high rate of car-to-person accidents. In the event of a car-to-pedestrian accident, the pedestrian is at a higher risk of sustaining severe injuries as a result of the physical disparity between the vehicle and the pedestrian. In addition, some residents and students living around apartment complexes and schools may lack pedestrian safety awareness. Therefore, it is necessary to raise residents' and students' awareness about traffic safety through guidance and education in schools and residential complexes. In apartment complexes, only certain roads are frequently equipped with medians. Therefore, it becomes necessary to install medians in accident-prone areas or near schools in order to ensure a safe traffic flow and prevent pedestrians from crossing without permission. Pedestrians will be able to use designated pedestrian crossing points on the median, thereby reducing the risk of collisions with vehicles. Additionally, speed bumps should be installed on roads near schools to reduce vehicle speeds, ensuring that they are

travelling at a safe pace, and to enhance drivers' awareness of their surroundings, ultimately minimizing the occurrence of traffic accidents. However, speed bumps should only be installed in appropriate locations, as they have the potential to damage vehicles, generate noise for the surrounding apartment complexes, and impede the flow of traffic.

Figure 6: QGIS Mapping(5)

The results of mapping the neighborhoods of Seongbok and Sanghyeon stations, based on the three major laws, are depicted in Figure 6. Although Seongbok and Sanghyeon stations have fewer traffic accidents than the area around Sujigacheong Station, it is evident that they still have a higher concentration of traffic accidents compared to other general locations. Because subway stations are frequently crowded gathering places, they are known for having high levels of traffic and congestion. Roads and intersections near subway stations are prone to traffic jams, which may result in vehicles cutting in front of each other, possibly leading to accidents. In addition, subway stations are typically connected to various modes of transportation, resulting in the convergence of bicycles, motorcycles, taxis, and other vehicles around the station, posing a risk for accidents. In order to ensure the safety of pedestrians, enhancing the pedestrian protection facilities near subway stations is crucial, as these areas experience a high volume of pedestrian traffic. To enhance pedestrian safety, it is important to enhance crosswalks and install extra pedestrian signals in order to ensure secure movement for pedestrians. In addition, various modes of transportation, such as bicycle paths, pedestrian walkways, and taxi stands, should be developed around subway stations to alleviate congestion and enhance safety. In addition to Sanghyeon and Seongbok stations, most subway stations experience a high number of traffic accidents, resulting in significant damage due to the heavy traffic volume. Therefore, efforts should be made to reduce the frequency of traffic accidents near subway stations.

Calculate Risk

Based on the results of this risk analysis, the road risk index was derived using ECLO.

- **ECLO**

The road risk index was derived using the Equivalent of Casualty Level by Objectives (ECLO). Method developed by the Korea Transportation Safety Institute. The severity of casualties is calculated by ECLO, which assigns weights based on the extent of damage and takes into account the number of casualties per accident.

$$ECLO = (1*MI) + (3*MO) + (5*SE) + (10*FA) \quad (3)$$

In Equation (3) show road risk index.
MI: Minor Injury
MO: Moderate Injury
SE: Severe Injury
FA: Fatal Injury
By using ECLO to derive a road risk index, you can determine how dangerous a particular road segment or intersection is.

- **ECLO Analysis by Incident Type**

Traffic accidents can be classified into three categories: car-to-car, car-to-person, and vehicle-only.

In the case of the Yongin traffic accident data used in this study, the number of 'car-to-car' accidents was 4,260, 'car-to-person' was 924, and 'vehicle alone' was 206. After applying ECLO to each type of accident, an analysis revealed that 'car-to-car' accidents had the highest number of casualties.

Table 2 shows the ECLO values by accident type.

Table 2: ECLO by Accident Type

Type Type	Injuries	Minor injuries	Serious injuries	Fatalities	ECLO
Car-to-car	5859	4669	1190	12	25936
Car-to-person	839	441	398	20	4352
Vehicle Only	147	82	65	9	808

- **Road Risk Index**

In this paper, we develop a road risk index based on the ECLO concept to represent the severity of human casualties in traffic accidents. The biggest cause of traffic accidents is human factors, although they can also be caused by a variety of other factors. Therefore, we have developed a road risk index that incorporates various factors. If you can determine the road risk index in advance, you can be aware of the level of risk and drive cautiously to prevent accidents. The road risk index is calculated by scaling the factors of weather, time of day, and intersection shape provided by the Yongin traffic accident data. Equation 2 displays the derived road risk index.

$$\text{Road Hazard Index} = ECLO * Xw * Xt * XT \quad (4)$$

In Equation (4):
$ECLO$ = Equivalent of Casualty Level by Objectives
X_w = Weather factors (sunny, snow, rain, fog, cloudy)
X_{time} = Time factor (day, night)
$X_{Traffic}$ = Intersection morphology factors (four-way, three-way, out-of-way, not intersection, turn)
However, when examining the fatality rate of traffic accidents due to weather over a five-year period (2017-2021) as reported by the Korea Expressway Administration, it becomes evident that rainy road accidents have a fatality rate of 2.1, whereas sunny day accidents have a fatality rate of 1.5. Therefore, while the number of accidents is highest on sunny days, the level of damage caused by traffic accidents is higher on rainy days. In addition to rain, foggy or cloudy weather can also interfere with drivers' visibility, making it difficult for them to see pedestrians or other vehicles, as well as maintain a safe distance between vehicles. On snowy days, snow not only limits visibility but also increases the likelihood of accidents by making the road slippery, reducing friction, increasing the vehicle's stopping

distance, and making it harder to control the vehicle. (Angın, M., 2021) (Zhang, Y., 2020) (Megnidio-Tchoukouegno, M., 2023) (Ashraf, I., 2019)

Table 3: Accident Ratio by Weather Factor

w.t type	sun	snow	rain	foggy	cloudy
Car-to-car	0.908	0.004	0.063	0	0.021
Car-to-person	0.891	0.008	0.071	0.001	0.022
Vehicle Only	0.908	0.010	0.073	0	0.009

Table 4: Accident Ratio by Time Factor

Time Type	Day	Night
Car-to-car	0.588	0.412
Car-to-person	0.565	0.434
Vehicle Only	0.520	0.480

Table 3 displays the weather factor associated with each incident type, represented as a percentage. The highest number of accidents occurred on sunny days for all three types of accidents. Table 4 displays the percentages of incident types based on the time factor. You can observe that all three types of incidents have a higher frequency during the day, but the ratio of incidents between day and night is not significantly distinct. During the week, traffic typically gets heavier, and people become more active, increasing the likelihood of a car accident. Key factors that can include traffic congestion are during rush hour and school hours in school zones. During daytime driving, traffic can not only be heavy, causing traffic jams, but the distance between vehicles can also be close. If drivers fail to maintain a safe distance, it can become difficult to react effectively to sharp turns or sudden acceleration, thus increasing the chances of a collision between vehicles. Although traffic is relatively lighter at night compared to daytime, the risks of driving can increase. The main factors contributing to nighttime driving are limited visibility, drowsy driving, and drunk driving. When driving at night, there may be less traffic compared to driving during the day. When traffic is lighter, drivers tend to speed up, thereby increasing the risk of accidents at night due to excessive speed. And, Table 5 displays the percentage of accident types according to the intersection shape factor. For all three types of accidents, the highest number of occurrences happened at non-intersections. However, the QGIS mapping revealed that a significant percentage of accidents took place at intersections, including the one near the Water District Station. An intersection is a point where multiple roads intersect, subjecting the surrounding roads to high traffic volumes of vehicles crossing each other. This often results in traffic jams and increases the likelihood of accidents around the intersection. (Delgado-Fernández, V.J., 2022) In addition, drivers at intersections are required to obey traffic lights, priority rules, and pay attention to avoid collisions with other vehicles at the intersection, and accidents often occur at intersections due to drivers' inattention, disregard for signals, and failure to maintain a safe distance. Compared to most non-intersecting roads, intersections have various obstructions such as buildings, vehicles, and traffic lights, which can make it difficult for drivers to see other vehicles or pedestrians when entering the intersection, resulting in traffic accidents. (Madlenˇák, R., 2018) (Zheng, Z., 2018)

Table 5: Accident Ratio by Intersection Type Factor

Type Type	intersection	three-way intersection	five-way intersection	Not an intersection	traffic roundabout
Car-to-car	0.346	0.257	0.002	0.384	0.002
Car-to-person	0.237	0.213	0	0.530	0.002
Vehicle Only	0.097	0.141	0.010	0.747	0

Table 6: Road Risk Index Table

Intersection	**sunny**	Day	37.006
		Night	34.159
	snow	Day	0.408
		Night	0.376
	Rain	Day	2.975
		Night	2.746
	Fog	Day	0
		Night	0
	Cloudy	Day	0.367
		Night	0.339

The road risk assessment matrix derived by calculating the corresponding road risk index is shown in Table 6. Table6 is a partial table of the road risk index calculated by combining the above three dynamic factors and ECLO, and shows the conversion of the road risk index of the 'vehicle alone' road risk index to the road risk index of the three-way and four-way intersection. For example, the probability of a 'vehicle-only' accident occurring at a four-way intersection in clear weather during the day is 808 * 0.52 * 0.908 * 0.097 = 37.006. The matrix provides road risk by synthesizing various information such as weather information and time factors, so it is expected to recommend safe routes to drivers.

Road Risk Assessment Matrix						
		Risk Assessment Phase				
		1	2	3	4	5
		Safety	General	Caution	Dangerous	Critical
Intersection classification	Traffic accident types					
intersection	Car-to-car	<50	<100	<200	<1000	>1000
	Car-to-person	< 1	< 10	< 50	< 100	> 100
	Vehicle Only	<0	<1	<10	<20	>20
three-way intersection	Car-to-car	<0	<10	<50	<1000	>1000
	Car-to-person	< 1	< 5	< 10	< 100	> 100
	Vehicle Only	<0	<1	<5	<50	>50
five-way intersection	Car-to-car	<0	<0.05	<0.2	<1	>1
	Car-to-person	0	0	0	0	0
	Vehicle Only	<0	<0.04	<0.1	<3	>3
Not an intersection	Car-to-car	<0	<5	<30	<100	>100
	Car-to-person	< 10	< 30	< 50	< 100	> 100
	Vehicle Only	<0	<3	<20	<150	>150
traffic roundabout	Car-to-car	<0	<0.05	<0.2	<1	>1
	Car-to-person	< 0.01	< 0.1	< 0.5	< 1	> 1
	Vehicle Only	0	0	0	0	0

Figure 7: Road Risk Assessment Matrix

4 Research Findings

Based on a dataset of traffic accidents in Yongin over a seven-year period, this study analyzed the provisions of the law that were most frequently violated. The most frequent violations were Article 5 (signal or instruction violations), Article 25 (intersection traffic law violations), and Article 48(1) (violation of the duty to drive safely). In addition, the location information of accidents was visualized in QGIS to identify areas with a large number of accidents. The road risk index was then calculated by analyzing the type of accident. Based on the derived road risk index, a road risk assessment matrix was created, and each score was classified into five levels: safe, general, caution, dangerous, and serious.

5 Conclusion

The number of traffic accidents in Yongin has been increasing each year. Based on this, we utilized the Yongin traffic accident dataset to identify the causes of the high accident frequency in the area and propose potential improvements. In addition, we calculated the road risk index to determine the specific risk level based on the type of accident. Through this study, we hope to contribute to the prevention of

traffic accidents in Yongin. Traffic accidents are often caused by a combination of factors rather than a single specific cause. To further investigate, it is crucial to incorporate additional information beyond weather factors, time factors, and intersection types used in this study in order to calculate the road risk index for specific accidents. Additionally, while analyzing traffic accident data in Yongin, we discovered that most accidents happened during sunny weather, but the likelihood of accidents increased significantly during inclement weather conditions like rain and snow. Therefore, when calculating the risk level, it is necessary to consider the level of damage caused by each factor and assign it a weight, such as ECLO. The finalized road risk assessment matrix was missing the number of 'car-to-person' accidents at intersections (backcountry) and 'vehicle-only' accidents at intersections (turns), which prevented the conduct of a risk assessment. To conduct a risk assessment in such cases, it is necessary to obtain traffic accident data for the entire Yongin area, as the data used in this study was collected by the Yongin West Police Station. The Korea Traffic Accident Research Institute indicates that the violation of safe driving accounts for more than half (61.3%) of all traffic accidents when categorizing drivers' accident factors into traffic violations. The most commonly violated legal provision during the seven-year period of traffic accidents from 2015 to 2021 in Yongin, Gyeonggi-do (which is examined in this paper), is Article 48, paragraph 1 (regarding the violation of the duty of safe driving).

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