Operational Analysis of 2+1 Roadway and its Use in Developing Geometric Design Standards in S Korea

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ABSTRACT

This paper presents the operational analysis results of applying 2+1 roadway in South Korea that is already in operation in European countries and decided to be applied soon in S Korea. In this analysis, traffic flows and crash occurrence characteristics obtained for a few sections of 88 Olympic Freeway, which was built more than twenty year ago as a two-lane road but improved recently to 2+1 roadway geometrics, were closely investigated. This analysis revealed that by using 2+1 roadway traffic flow conditions could be improved noticeably as the reported cases in European countries, and that safety effects including crash frequency and crash severity could be substantial. An intermediate S Korean geometric design standard for 2+1 roadway published 2009 was also outlined for international comparisons. This research captured some of important traffic flow characteristics on 2+1 roadway in S Korea, and this result should be useful for forthcoming 2+1 roadway designs.

Key Words: 2+1 roadway, Transition Areas, Cross Section, Safety Effect, Traffic Flow, Intermediate Geometric Design Standard

1. INTRODUCTION

Two-lane highways contribute to form the national arterial highway system in South Korea. Although performing well at most two-lane highways, South Korean rural roads suffer from reduced mobility problems at mountainous terrain because drivers tend to travel at lower vehicle speeds due to poor geometric conditions at mountainous terrain areas. Frequently inappropriate access managements on two-lane highways aggravate operational problems on two-lane highways. In highway planning process, it is taken for granted that a significant amount of traffic volume increase would require making two-lane highways into four-lane highways. However, when the volume level is still below the capacity of four-lane highways and it takes a long period until to reach the capacity, the simple highway expansion into four-lanes may not be a suitable solution. Capacity values for two-lane highway and four-lane highway are quite different, and construction cost for four-lane highway jumps up significantly. Therefore, instead of expanding a two-lane highway into four-lane, it is required to apply intermediate types of highway, and some countries have been using 2+1 road for this reason. Lately, South Korea moves forward to applying 2+1 road to maximize highway investment efficiency, and because there are many remote rural areas where traffic demand seems never meet four lane capacity in spite of these areas asking for highway construction to stimulate regional development, 2+1 road design is attracting engineers attention. Also, with other nations experiences that 2+1 roadways are attributed to reduce head-on collisions compared to existing two-lane highways, this new highway design concept seems to get a high momentum.

This study reviews the characteristics of existing two-lane highways and provides an overview of 2+1 roadways which are currently in use internationally. Also, this study analyzes the characteristics of traffic flows and crash data obtained in one section of the 88 Olympic Freeway in South Korea which was built more than twenty year ago as a two-lane road and partially improved to have better geometrics, the forms identical to 2+1 roadway.

2. 2+1 ROADWAYS IN EUROPEAN COUNTRIES

2+1 roadway has three-lanes and the direction with higher volume operates in two lanes. In the two lanes, faster vehicles use the median lane (passing lane). Usually the length of 2+1 roadway is 1-2 km. As shown in Figure 1, the passing lanes are alternatively located in both directions to provide drivers with more opportunities of overtaking. Table 1 shows the graphical representation of 2+1 roadways currently used in six European countries.

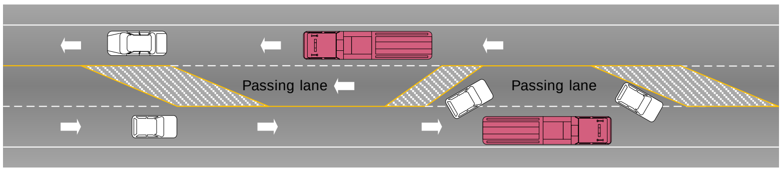

Figure 1 Graphical Representation of 2+1 roadway

Table 1 Geometric designs of 2+1 roadways in European countries

Category			Sweden	Germany	Finland	Denmark	Scotland	Ireland
Speed Limit(km/h)			90~100	100	-	80~90	Rural: 85~120, Urban: 30~80	
AADT			4,000~20,000	15,000~25,000	14,000	7,000~14,000	9,800	11,600~17,250
Passing Lane Length(km)			1.0~2.5	1.0~1.4	1.5	1.55	-	1.0~2.0
Lane width(m)	2-lane	1	3.25	3.25	3.25	3.25	3.5	3.5
		2	3.25	3.25~3.5	3.5	3.25	3.5	3.5
	1-lane		3.75	3.5~4.25	3.75	3.5	3.5	3.5
Shoulder width(m)			1.0	0.25	1.25	1.0	1.0	0.5~1.0
Critical transition area length(m)			300	180	500	300	500	300
Non-Critical transition area length(m)			100	≥ 30	50	-	-	50
Median type			Guard Cable	Lane Marking	Planning	Lane Marking	Lane Marking	Guard Cable

3. A Case Study

88 Olympic Freeway in S Korea has a highest fatal rate of 78%, compared to the nationwide fatal rate of 8%. This freeway has two lanes in both direction, and people used to criticize the Korea Highway Corporation who is responsible for freeway maintenance that this lower type freeway design is the main problem of involving the abnormally severe crashes. To reduce these crashes, the KHC has redesigned two stretches of this freeway by applying alternative passing lanes in addition to the initial cross sections. Since their geometric designs are similar to 2+1 road designs that are now in operation in Europe, this research team has decided to make the operational and safety analysis of 2+1 roadway on these sites to understand how 2+1 roadway would accommodate South Korean motorists.

3.1 Field Survey Sites

Table 2 shows the detailed geometric designs of the sites. The lengths of the passing lanes are 1.0-1.2km and traffic volume is approximately 8,000 vehicles per day. The passing lanes were made available by restriping the existing roadway pavement sections, and the finalized cross section shows 13.1m width.

Table 2 88 Field survey sites and their geometric outlines

Location	Goseo[East Goryeong↔Goryeong]	Daegu[Namwon↔SouthJangsu]	Remarks
	166.7~167.8km(two locations)	63.0~66.0km(two locations)	passing lane (1,1km)
Radius of curve	600m	700m	
Vertical grade	2.34%	3.19%	
Traffic volume	AADT approximately 8,000/day		183km from the beginning point

Figure 2 shows the cross section of the sites. It is to be noted that emergency parking spaces within shoulders are added intermittently because of substandard shoulder widths of 0.54-0.6m.

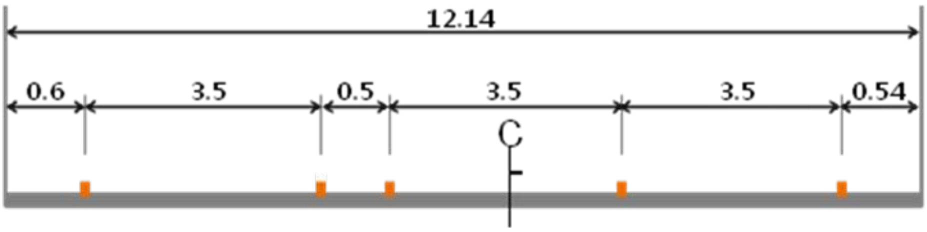

Figure 2 Cross section for the field sites

Table 3 outlines how the field survey sites were geometrically improved to accommodate fast moving vehicles in the presence of slow moving vehicles in traffic flow.

Table 3 Geometric Improvement done for the survey sites

Items	Improvements and their effects	Remarks
Length of passing lane	- Increased	- Depending upon traffic volume, the existing 900m length limits cannot accommodate passing demand
Lane changing maneuver	- More convenient and safer	- Median lane is for fast moving vehicles - Shoulder lane is for slow moving vehicles
Flows in transition zones	- Diverging area: clear road marking is required - Junction: sufficient transition length is required	-

Road marking, upstream guide sign, and other traveler information	- Junction road marking (solid line + dotted line) - Repeated sign placements on diverging and merging areas to warn motorists	- Combine solid line + dotted line in transition areas

3.2 Traffic Characteristics

In this research, video cameras were used to collect traffic volumes, speeds, headways and platoons on upstream and downstream sites. Voice recording were simultaneously made to record vehicle plate numbers passing the sites. Figure 3 illustrates the survey locations: p1 (upstream), p2 (the starting of the passing lane), and p3 (downstream).

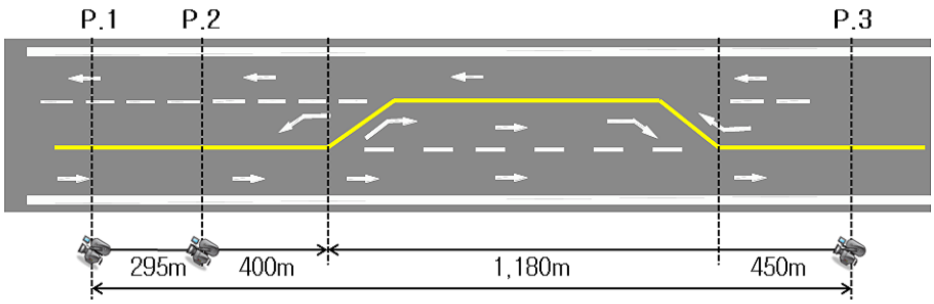

Figure 3 Camera positions

Collected data involve mean speeds, average percent of vehicles in platoon, and platoon sizes. This study has applied the platoon definition of vehicles following a slow moving vehicle with less than 3 seconds headway. Table 4 shows the summary of traffic flow.

1. While traffic volume levels at two upstream areas were 662 vph with 14% heavy vehicles, the ones at downstream was 674 vph with 13.3% heavy vehicles. This must be related to measurement error.
2. At the immediate downstream, a 20 km/h speed jump was recorded.
3. Downstream showed a smaller platoon size. This must be resulted from passing maneuvers within the passing lane.
4. Percent of vehicles in platoon decreased from 88.7% at upstream to 80.4% at downstream.
5. In summary, passing lanes assisted in improving traffic flow performances.

Table 4 Traffic flow summary

Observation spot Observation item	P.1	P.2	P.3	P.2 VS. P.3Variance Comparison
Traffic volume (No. of vehicles/hr)	662	662	674	+1.8%

No. of vehicle group	129	131	130	-0.8%
Average no. of vehicles within platoon	4.5	4.5	4.2	-7.1%
Total number of vehicles forming platoon	577	587	542	-8.3%
Average speed of space (km/hr)	77.8		97.5	+25.3%
Percent of vehicles platoons	87.2	88.7	80.4	-10.3%

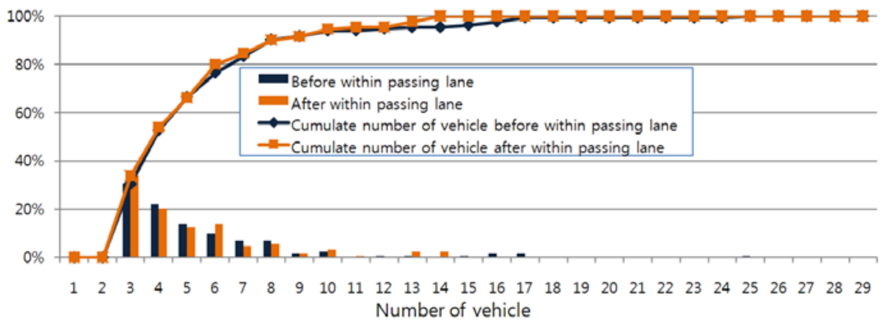

Figure 4 Observed platoon size cumulative distribution

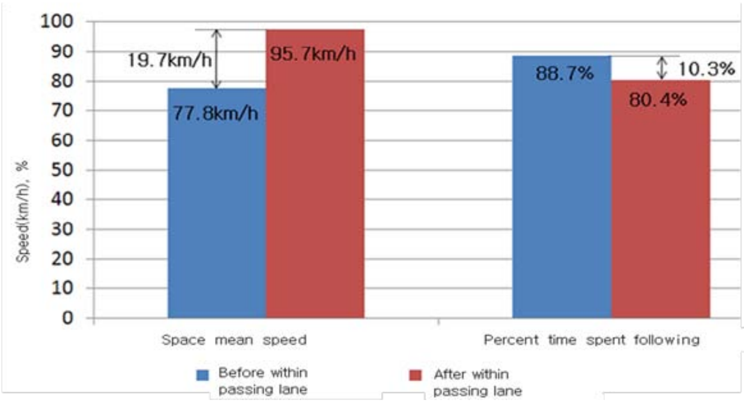

Figure 5 Observed Before and after speed data

3.3 Crash data

Table 5 shows the crash comparison for the before and after periods separated by the passing lane addition. It can be said that passing lane addition helped decrease total, fatal, and injury crashes, and this conclusion is particularly true when considering the before and after period time sizes.

Table 5 Crash comparison for the before and after passing lane addition

	Location (km)	Recorded Crashes					
		No. of crashes		Deaths		Casualties	
		Goseo	Daegu	Goseo	Daegu	Goseo	Daegu
Before construction (1999~ 2007)	Goryeong→East Goryeong (166.7~167.8)	2	3	1	4	3	2
	East Goryeong →Goryeong (168.0~169.1)	2	3	1	2	6	0
After construction (2008. 7~ 2008. 12)	Goryeong→East Goryeong (166.7~167.8)	0	0	0	0	0	0
	East Goryeong →Goryeong (168.0~169.1)	0	0	0	0	0	0

4. 2+1 Roadway Design

4.1 Standard Cross Section

An intermediate design guideline for 2+1 roadways in South Korea was made available last year, and in the guideline it is recommended that 2+1 road design be applied for the following two cases:

Case 1) A road surely to be expanded into four-lane highways

Case 2) A road to be specifically made into 2+1 roadways

Table 6 and Table 7 highlight the standard lane configuration plan and cross sectional width design standards in the intermediate design.

Table 6 Lane configuration plan for 2+1 roadway

	Before (No. of lanes)			After (No. of lanes)			Remarks
	Normal	Tunnel	Bridge	Normal	Tunnel	Bridge	
Case 1	2	2	2	3	2	2(3*)	Secure width for 1-lane
Case 2	-	-	-	3	2(4*),	2(3*,4**)	*Newly construct 1-lane road **Newly construct 2-lane roadway

Table 7 Cross sectional width design standards (unit: meter)

Right-Of-Way	Median Lane		Median	Shoulder lane	Shoulder
	1-lane road	2-lane roadway			
13.5	3.25	3.25	0.5	3.5	1.5*2
14.5	3.25	3.25	1.5	3.5	1.5*2

Also, Table 8 summarizes the horizontal and vertical design criteria for the 2+1 roadway intermediate design standards.

Table 8 Horizontal and Vertical Design Criteria for S Korean Intermediate Design Standard

<table>
<tr><th colspan="3">Category</th><th colspan="2">S Korea (2-lane)</th><th colspan="2">Europe (2+1 roadway)</th><th>S Korea(2+1 roadway)</th></tr>
<tr><td rowspan="4">Minimum plane radius of curve(m)</td><td rowspan="4">Partial grade(%)</td><td>5</td><td colspan="2">-</td><td colspan="2">360</td><td>360</td></tr>
<tr><td>6</td><td colspan="2">200</td><td colspan="2">-</td><td>200</td></tr>
<tr><td>7</td><td colspan="2">190</td><td colspan="2">180</td><td>190</td></tr>
<tr><td>8</td><td colspan="2">180</td><td colspan="2">-</td><td>180</td></tr>
<tr><td rowspan="2">Sight distance (m)</td><td colspan="2">Non-passing SD</td><td colspan="2">110</td><td colspan="2">120</td><td>110</td></tr>
<tr><td colspan="2">Passing SD</td><td colspan="2">480</td><td colspan="2">410</td><td>480</td></tr>
<tr><td colspan="3" rowspan="2">Vertical grade (%)</td><td>Level terrain</td><td>5</td><td>Newly opened section</td><td>4~5</td><td rowspan="2">5~7</td></tr>
<tr><td>Mountainous terrain</td><td>7</td><td>Reformed section</td><td>5~6</td></tr>
<tr><td rowspan="2">Variable ratio of vertical curve(m/%)</td><td colspan="2">Bulge</td><td colspan="2">30</td><td colspan="2">30</td><td>30</td></tr>
<tr><td colspan="2">Sunken-in</td><td colspan="2">25</td><td colspan="2">20</td><td>25</td></tr>
<tr><td rowspan="3">Maximum partial grade(%)</td><td colspan="2">Rural area</td><td>Snow and cold region</td><td>6</td><td colspan="2">7</td><td>6~8</td></tr>
<tr><td colspan="2"></td><td>Other region</td><td>8</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">Urban area</td><td colspan="2">6</td><td colspan="2">5</td><td>5</td></tr>
</table>

4.2 Length Standards and 2+1 Roadway in other Areas

Considering European design standards shown in Table 9, the intermediate design standard states that the minimum length of 2+1 roadway should 1.0 to 1.5km.

Table 9 Length design standard being used in European countries and proposed standard for S Korea

	Germany	Sweden	Ireland	Finland	Denmark	S Korea
Diverging area length : Lnc(m)	30	100	50	50	-	90
Junction length : Lc (m)	180	300	300	500	70~300	280
Length of passing section : Lp(km)	1.0~1.4	1.0~1.25	1.0~2.0	1.5	0.35~1.55	1.0~1.5
Total length : L(km)	1.21~1.61	1.4~1.65	1.35~2.35	2.05	0.42~1.85	1.375~1.875

Also, it states that the minimum length of the diverging area should be 90m, and that the one for the merging area should be 280 m. Figure 6 shows the typical transitional area configuration.

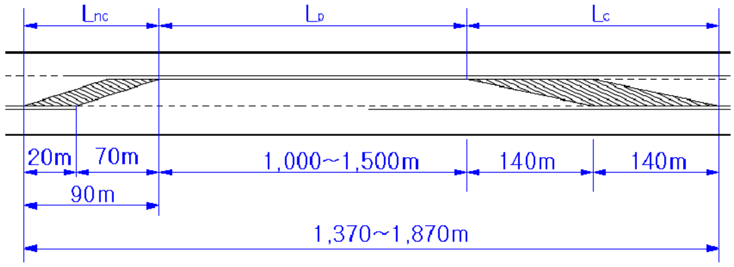

Figure 6 Configuration of the transition area for 2+1 roadway

Interestingly, the intermediate design standard to be used in South Korea suggests several unconventional intersection types as shown in Figure 7 that would be of service when applied in remote area 2+1 roadways. With light traffic volume, these designs appear operational to save vehicle delay and crashes.

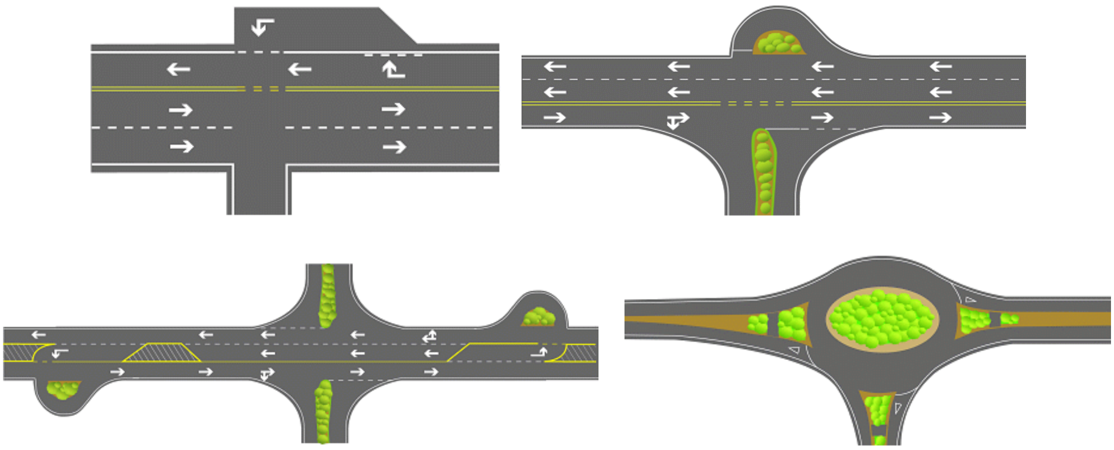

Figure 7 Unconventional intersection types

Finally, 2+1 roadway can be applied to facilitate traffic calming around residential areas. Various designs are available and the design flexibility associated with 2+1 roadway seems to be unique in such conditions. For example, by applying 2+1 roadway as shown in Figure 8 to existing two-lane roads, the section that passes through the residential zone can be regulated so naturally that most motorists do not feel that they are under any regulated conditions.

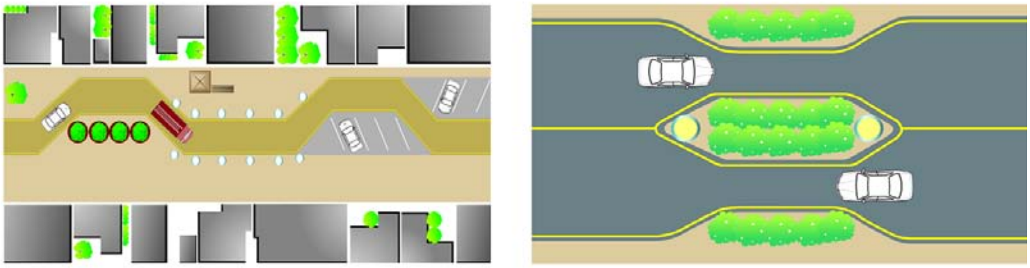

Figure 8 Design of residential zone

5. Findings and Conclusion

There are numerous two-lane highways in rural areas, but their expansion to four-lane highways may be not practical when projected traffic volume levels do not reach economically feasible values. Nonetheless, there are cases where the expansions are in immediate demand. To deal with this problem, 2+1 roadway design in South Korea was proposed in recent years, and they are highly expected to make two-lane highways operate effectively and safely as proved in many European experiences.

This study estimated the capability and feasibility of the new "2+1" roadway in existing two-lane highways in S Korea. One section of 88 Olympic Freeway whose geometric condition is identical to the geometric of 2+1 roadway was selected in this research to analyze the operational and safety effects associated with 2+1 placement in S Korea. The operational estimations have show that the average speed of 2+1 roadway would increase by about 19 km/hr and 10% of the delay would be reduced. In terms of safety effect, this research estimated a significant amount of crash reduction.

ACKNOWLEDGEMENTS

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