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Assessing the Effectiveness of Exclusive Truck Lanes: A Korean Expressways Case Study

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Abstract

This study investigates the operational and safety impacts of introducing exclusive truck lanes on the Gyeongbu Expressway in South Korea, addressing the necessity of such lanes due to the disparities in vehicle weight and performance between trucks and passenger cars. The study focused on the 33.2 km, one-way, four-lane Chilgok-Mulryu to Gimcheon segment, adhering to international installation criteria. Using the micro-simulation tool VISSIM, the rightmost lane was modeled as exclusive for trucks, and traffic operations and safety were analyzed under varying conditions of Level of Service (LOS). Under LOS C, the exclusive truck lane reduced the speed standard deviation (a surrogate safety measure) with minimal travel speed reduction. Conversely, under LOS A with low traffic, average travel speed declined, and speed standard deviation increased due to limited truck usage. These findings highlight the need for flexible truck lane management tailored to traffic and road conditions.

Keywords: exclusive truck lane, simulation, VISSIM, travel speed, speed standard deviation

1. Introduction

Various nations, such as the United States, Canada, and the United Kingdom, have adopted truck-only roads and exclusive lanes to mitigate fatal accidents involving trucks and accommodate advancements like truck platooning. Delving further into this matter, exclusive truck lanes were implemented by the United States and Canada to enhance road safety. Conversely, in the United Kingdom, the primary objective is alleviating road congestion. Ultimately, the rationale behind introducing exclusive truck lanes varies slightly from one country to another. These initiatives have demonstrated effectiveness in enhancing safety and mobility, sparking a growing interest in establishing exclusive lanes for freight vehicles. Trucks possess distinctive design features that make them prone to causing severe accidents in collisions with passenger vehicles. Moreover, the typically lower speed limits for trucks on expressways than for other vehicles underscore the importance of segregating truck driving lanes whenever possible.

The evolution of platooning technology has spurred active discussions on providing dedicated lanes for trucks to leverage this innovation. Additionally, the emergence of electric trucks has also led to the design of electric truck-only lanes employing a track concept. A truck-only or truck-exclusive lane is a designated pathway exclusively reserved for trucks, aiming to bolster logistics competitiveness and enhance driving safety. The current environment presents an opportune moment to deliberate on the implementation of exclusive lanes and roads for trucks, aiming to minimize accident damage resulting from mixed vehicle types and elevate the transportation competitiveness of lorries.

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This study aims to identify suitable road segments on Korean highways for the implementation of truck-only lanes. Subsequently, it utilizes microscopic simulation analysis techniques to assess the effects of introducing these lanes on traffic flow and safety. The investigation focuses on converting the existing rightmost lane into an exclusive lane for trucks and analyzing its operation. The effectiveness of the truck-exclusive lane is being scrutinized using VISSIM, a microscopic traffic flow analysis program. The comparison involves evaluating average travel speed and its standard deviation with and without the dedicated lane. The standard deviation of average travel speed is an index influencing traffic accidents, as traffic flow stability correlates with the similarity in speed among vehicles. The outcomes of this study aim to offer insights into the implementation of exclusive lanes for freight vehicles, akin to bus-only lanes, by restricting the right-of-way for other cars.

The following section delineates international standards for installation, provides examples, and discusses the effects of installing truck-only lanes. Additionally, Section 3 outlines the methodology employed to simulate the impact of introducing truck-only lanes on specific expressway segments in Korea. Subsequently, Section 4 presents the simulation findings and initiates a discussion. Finally, the conclusion underscores the imperative of implementing dedicated truck lanes on Korean highways, emphasizing their significance for traffic safety and operational efficiency.

2. International Operational Practices

Before evaluating the feasibility of implementing truck-only lanes on Korean expressways, an analysis was first conducted on cases in foreign countries where such lanes are already in operation. Primarily through the examination of installation standards, operational practices, and their effects, the potential applicability of truck-only lanes in Korea was assessed.

2.1. Installation criteria

According to the Transportation Association of Canada (2014), highway-related truck lanes are classified into five types. These include: 1) physically separated cargo-only lanes from general vehicle lanes on freeways; 2) operationally separated truck lanes on freeways that are not physically separated; 3) truck climbing lanes; 4) truckways that connect cargo terminals to major freight generators; 5) truck bypasses that are installed as detours for trucks in bottleneck areas [1].

The installation standards for truck-only lanes vary across countries, but the primary criteria commonly used are truck traffic volume and total traffic volume. Moreover, if the accident rate involving freight vehicles exceeds the national average at a particular location, installing a dedicated freight vehicle lane is advisable.

In 2014, the Transportation Association of Canada outlined key factors and standard values for each type of dedicated truck lane. For instance, they recommend that truck-only lane should be considered when the total traffic volume is between 80,000 and 120,000 vehicles/day, the ratio of trucks is between 14 and 30%, the distance from the freight location is 3 km or less, and the number of accidents per million vehicles is 63 or more, or the truck accident rate is higher than the national average. Furthermore, if the freight lanes are physically separated, they must have a minimum length of 16 km. If they are not physically separated, there must be a minimum of four lanes in each direction [1].

The Georgia Department of Transportation evaluates the need for exclusive lanes by considering traffic congestion in general lanes, major transportation routes, economic regions, cargo bottleneck areas, and business logistical paths. They do this when truck traffic exceeds 30,000 daily vehicles in both directions. The California Department of Transportation (Caltrans) installs truck lanes based on hourly volumes and the number of trucks. Meanwhile, the Florida Department of Transportation (FDOT) proposes a truck-only road or lane, considering factors such as proximity to airports, ports, terminals, and railroad facilities, as well as truck ratio, level of service, number of truck accidents, and number of trucks [2].

2.2. Examples of operations in practice

There are various instances of exclusive truck roadways in the United States. Some roads, like the I-5 Expressway in California (refer to Fig. 1(a)), have a lane exclusively for cars that any vehicle can use. Still, only High Occupancy Vehicles (HOV) are permitted to use the lane during rush hour. The California I-5 also has two lanes exclusively for trucks. In the cargo-only lane of the I-5 Expressway, trucks are allowed to use the rightmost lane if there are three lanes in each direction and the two right lanes if there are four lanes in each direction. However, passenger cars are also allowed to use the dedicated lanes. Certain sections of the I-95, I-75, and I-4 highways in Florida have specific restrictions on truck lanes, and penalties are imposed for violations to ensure they are used solely for trucks.

The dual-dual roadway spanning 33.5 miles, which links New Jersey (refer to Fig. 1(b)) and Delaware in the United States, is managed by using physical structures to segregate the inner lanes for passenger cars and the outer lanes for all vehicles. Rotterdam, the Netherlands, has multiple truck lanes designed to make cargo handling easier at major ports. The A16 highway has 12 km-long truck lanes at seven different locations, while the A20 highway has approximately two km-long truck lanes. When heading northbound on the A16 Expressway (refer to Fig. 1(c)), three express lanes are available, but only one is designated for buses and trucks. However, when heading southbound, all lanes are used as general lanes.

The Queensland Government of Australia mandates that on the M1 road between Brisbane and the Gold Coast, cargo vehicles weighing 4.5 tons or more are restricted to using only the two shoulder lanes. They can overtake other vehicles but must remain within these designated lanes to minimize interaction with passenger cars [3]. In New Zealand, truck priority lanes are designated on highway ramps equipped with traffic lights to facilitate uninterrupted entry for trucks without stopping or losing momentum, particularly on sloped ramps. This initiative is founded on the premise that providing priority lanes for trucks enables them to maintain appropriate speeds on the highway, thereby reducing delays caused by trucks [4].

(a) I-5 (California) (b) Dual-dual roadway (New Jersey) (c) A16 motorway (Netherlands)

Fig. 1 Illustrations of the exclusive truck lane [5]

2.3. Operational consequences

In 2003, Fischer and colleagues conducted a feasibility analysis to assess the viability of constructing truck-only lanes on SR-60 and I-710 roads in California. The study revealed that the presence of such lanes led to an increase in truck demand, while removing these lanes decreased demand. Additionally, certain studies have utilized microscopic traffic analysis simulations to examine the impacts of truck-only lanes or lane restrictions [6].

An examination of scenarios using VISSIM in Tennessee and Texas revealed that introducing truck lanes had minimal effects on conventional metrics like average speed, the speed differential between cars and trucks, and the overall level of service of the road [7]. However, another study assessing truck-only lanes' safety and operational efficacy via VISSIM showed improved average speeds on certain highways. Nonetheless, some roads experienced adverse outcomes such as heightened lane changes, reduced average travel speeds, and longer queues. This phenomenon was also observed in the analysis [8]. By analyzing the impact of truck-only lanes based on the truck ratio on the Gardiner Expressway in Toronto, Canada, using a microscopic simulation tool, it was observed that the effectiveness of truck-only lanes was most pronounced when the truck ratio exceeded 15% of the total vehicle count [9].

In 2007, Fontaine and colleagues evaluated the operational and safety aspects of Virginia's two types of truck lanes. The first road, Road 1, is a one-way street with 3-4 lanes, where trucks cannot enter the overtaking lane. According to the study, the annual average daily traffic volume of 10,000 vehicles or less improves safety. However, incidents increase when the traffic volume exceeds a certain level, although the study did not provide specific results for this case. The study examined a two-lane, one-way road where slower trucks below a particular speed were limited to the right-hand lane. Implementing these lanes resulted in a 23% reduction in accidents and increased travel speed by 5.5 mph. However, no significant safety outcomes were observed. The study suggested that further investigation was necessary to address the issue of non-truck vehicles using the overtaking lane at low speeds [10].

Regarding the incidence of traffic accidents within dedicated truck lanes, research conducted on SH 225 LaPorte Freeway, where such lanes have been in place since 2003, revealed a decrease in accidents from an average of 7.9 occurrences per week to 2.9 occurrences per week following the introduction of these lanes. Furthermore, the study confirmed that 90% of passenger car drivers favored truck-only lanes, citing safety concerns [11].

In 2008, Kobelo and colleagues investigated the impact of truck-only lanes on accident rates in 128 sections of highways in Florida. They developed a model that considered multiple explanatory variables related to accident frequency for each section. The study found a correlation coefficient of 0.3627 between the presence of exclusive lanes for trucks and the number of accidents, indicating a 4% reduction in accident rates in sections with truck-only lanes. Furthermore, the study revealed that an increase in the number of trucks on the highway decreased the opportunity for passenger cars to change lanes, resulting in fewer accidents. The analysis suggested that if the ratio of trucks on the road increased from 2 to 15%, the annual number of accidents could decrease by 22% [12].

Though the dual-dual roadway is not designated exclusively for freight vehicles, safety measures have been implemented along 33.5 miles of the dual-dual roadway on the highway connecting New York and Delaware. Here, the passenger car exclusive lane (inner lane) and the general lane (outer lane) are separated by a physical structure. The study revealed that the traffic accident injury rate on this roadway segment was 34.9-49.6% higher than that on general roads, indicating that segregating traffic lanes by vehicle type does not always yield solely positive outcomes [13]. Furthermore, in line with numerous other research findings, a study utilizing the Empirical Bayes method to estimate future collisions between vehicles, with a focus on truck lane restrictions in North Texas, also indicated a decrease in the risk of accidents involving large trucks on bidirectional six-lane roads [14].

In 2009, the Federal Highway Administration (FHWA) conducted a study to evaluate the practicality of building a dedicated truck lane specifically for Longer Combination Vehicles (LCV). The study estimated the advantages of pavement quality, congestion reduction, safety improvements, increased trucking productivity, and reduced emissions from converting existing Single-Trailer Trucks (STT) to LCVs. Safety benefits constituted around 30% of the estimated overall benefits [15].

In 2012, Ishak and colleagues assessed the operational and safety effects of various truck lane restrictions and differential speed limits on the I-10 highway. The study found that compliance with exclusive lanes for trucks was higher at the midpoint than at the start and end points of the lanes, with an estimated policy compliance rate of 60-80%. The implementation of exclusive lanes for trucks increased the use of trucks in the left lane, and it was confirmed that they drove in the left lane to overtake other trucks. The number of collisions with trucks decreased by 76%, from 81 before the introduction of the lanes to 19 after. These findings suggest introducing exclusive truck lanes can improve safety by reducing collisions [16].

Studies assessing the effectiveness of truck-only lanes as a transportation infrastructure measure have been conducted continuously until recent years. Jianwei et al. emphasized the role of freight lanes as one of the transportation infrastructures in enhancing economic activity by improving supply chains and reducing logistics costs, contributing to broader regional development and economic growth [17]. Focusing on how truck-only lanes can reduce congestion and emissions in urban corridors, the review article from Ana, Juan, and Andres examined various lane management strategies and their role in enhancing metropolitan traffic efficiency, while stressing the importance of adaptive planning to balance freight and passenger vehicle needs [18].

2.4. Rationale for implementation

In South Korea, a designated lane system for large vehicles exists; however, the violation rate is high, and accidents resulting from system violations are significant. In 2005, 86.1% of accidents involving large vans or trucks over 1.5 tons on highways with three or more lanes were due to non-compliance with the designated lane system. Therefore, there is a pressing need for stronger policies to address this issue. Implementing exclusive lanes for trucks that segregate them from small cars could be a solution to reduce accidents caused by trucks.

Furthermore, introducing dedicated truck lanes is expected to enhance logistics efficiency by improving truck travel speed and punctuality. Additionally, it may help reduce maintenance costs by minimizing road damage. Given the domestic traffic conditions and the evolving logistics system, dedicated truck lanes can be a crucial policy measure for efficient and safe road operations. Therefore, it is imperative to review and consider the establishment of such lanes in Korea [19].

3. Evaluating the Operational Effects of Truck-Only Lanes

In South Korea, there are currently no dedicated truck lanes on highways. Consequently, analyzing the operational impact of such lanes post-implementation is impractical. Therefore, this study aims to employ microscopic simulation techniques to anticipate the effects of installing and operating truck-only lanes.

3.1. Methodology

This research employed a microscopic traffic flow simulation approach using the specialized program VISSIM to assess the potential impact on traffic flow and safety when converting one lane in a specific section of the highway into an exclusive lane for freight vehicles. VISSIM, a detailed microscopic traffic simulation tool, offers high realism and precision. It can replicate diverse traffic scenarios by intricately modeling road networks, intersections, vehicles, and driver behavior, accurately reflecting real-world conditions and variations in these factors. Widely utilized in the transportation field, VISSIM can monitor meaningful responses to variables such as traffic flow, vehicle speed, and delay time. This study quantitatively evaluated the traffic effects resulting from the implementation of exclusive truck lanes. This was achieved by collecting and analyzing travel speeds and speed standard deviations obtained through simulations for each scenario.

3.2. Study area

A comprehensive review of the entire highway network in South Korea was conducted to identify the simulation target area, utilizing the following primary selection criteria. Firstly, the designated lanes should be installed on roads with a minimum of four lanes in one direction, as one lane needs to be exclusively allocated for trucks. For instance, even on a three-lane highway, passenger cars and buses will use the first lane to overtake other vehicles. Therefore, if a dedicated truck lane is installed on the third lane in the scenario, all vehicles would have to run on the remaining lane, resulting in an operational issue. Secondly, the traffic volume of trucks should exceed the average traffic volume per lane. This ensures that if the utilization of the truck-only lane is low, it does not compromise the overall road efficiency. Therefore, installing dedicated lanes in areas with substantial truck traffic is preferable.

Following an assessment of the 2020 traffic and network data, 53 highway sections (272.7 km) that fulfilled the first and second criteria were identified across the country. Thirdly, the designated lanes must be installed in segments with a minimum spacing of 2 km between interchanges. If the dedicated lane is positioned on the far-right lane, it may lead to friction with diverging and merging traffic before and after interchanges, thus decreasing operational efficiency. Finally, the designated lane segment should have a minimum length of 20 km or more. This is because longer segments are essential for stable truck driving and operational efficiency.

Based on these four criteria, three sections were shortlisted: the Chilgok Mulryu-Gimcheon junction section, the Gyeongsan-Gumho junction section of the Gyeongbu Expressway, and the Jinju-Sanin junction section of the Namhae Expressway. Among these sections, the Gyeongsan-Gumho junction section was unsuitable for evaluating truck-only lanes due to its high traffic volume and congestion. Similarly, the Jinju-Sanin junction section had multiple interchanges located every 2-3 km, making it challenging to anticipate the efficiency of dedicated lanes. Consequently, the Chilgok Mulryu-Gimcheon junction section of the Gyeongbu Expressway was ultimately chosen as the study area for simulations (refer to Fig. 2). This four-lane road has a total length of 33.2 km and a high volume of truck traffic, with three interchanges located at Gumi, Namgumi, and Waegwan.

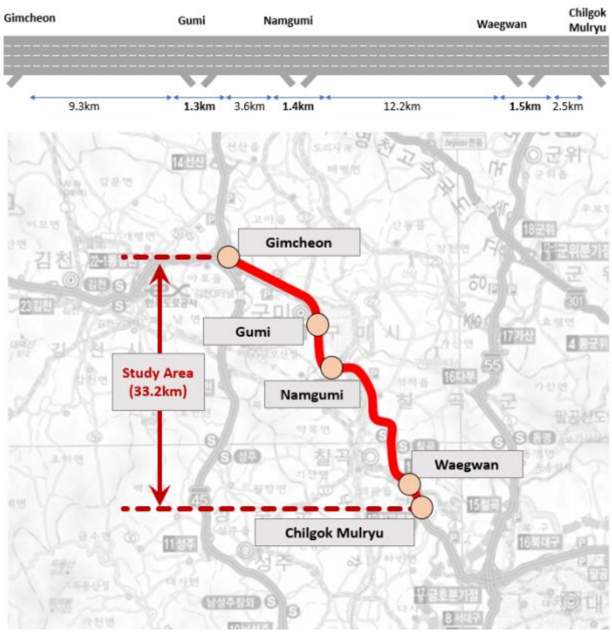

Fig. 2 Location of the study area

3.3. *Preparations of alternatives*

An analysis was conducted using VISSIM, a traffic simulation program, at the acceptable level to investigate the impacts of the specialized truck lane. The scenarios were divided into two categories: non-operation of the dedicated lane (Scenario I) and operation of the dedicated lane (Scenario II). Detailed scenarios were created for each scenario by selecting two time periods, as shown in Table 1.

Table 1 Analytic Scenarios

Scenarios \ Time	Period 1 (4:00 PM- 5:00 PM)	Period 2 (09:00 AM - 10:00 AM)
Scenario I (do nothing)	Scenario I-1	Scenario I-2
Scenario II (with truck-only lane)	Scenario II-1	Scenario II-2

The Ministry of Land, Infrastructure and Transport, overseeing the planning, construction, and maintenance of Korea's entire road network spanning 114,314 km as of December 31, 2022, has established the third Thursday of October annually as the pivotal date for the nationwide traffic volume survey, informed by years of research. On this chosen day, resources will be deployed at 3,793 specified locations along the country's roads (including 657 for routine surveys), conducting a 24-hour assessment of traffic volume categorized by vehicle type, direction, and time. The results become the basis for nearly all initiatives and studies about Korea's transportation infrastructure. Accordingly, the analysis utilized traffic volume data obtained from the nationwide annual highway traffic survey conducted on Thursday, October 22, 2020. The corresponding traffic conditions are summarized in Table 2. Period 1, spanning from 4:00 PM to 5:00 PM, represents the peak hour for the section, despite maintaining a LOS C. In contrast, Period 2, from 9:00 AM to 10:00 AM, corresponds to a non-peak hour with an LOS A.

Table 2 Traffic conditions in each scenario

Classification		Section	Volume (vehicle/hour)	Truck volume (vehicle/hour)	Truck ratio (%)
Period 1	4:00 PM- 5:00 PM	Gimcheon - Gumi	2,791	892	32.0%
		Gumi - Namgumi	3,145	983	31.3%
		Namgumi - Waegwan	3,521	1,050	29.8%
		Waegwan – Chilgok Mulryu	4,320	1,226	28.4%
Sum			13,777	4,151	30.1%
Period 2	09:00 AM−10:00 AM	Gimcheon - Gumi	1,700	667	39.2%
		Gumi - Namgumi	2,015	782	38.8%
		Namgumi - Waegwan	2,237	853	38.1%
		Waegwan – Chilgok Mulryu	2,787	1,043	37.4%
Sum			8,739	3,345	38.3%

The location of the truck-only lane can be decided between the center and the far-right lane. While the center lane provides advantages in securing the right of way, it goes against the intended purpose of the designated lane under the current Road Traffic Act, which mandates that heavy vehicles should travel in the right lane. Moreover, the narrowness of the median presents challenges for long-distance truck drivers.

Additionally, trucks with limited acceleration and deceleration capabilities may cause significant inconvenience to other vehicles when entering or exiting the interchange area. Alternatively, placing the truck-only lane in the far-right lane aligns with the existing designated lane system. It can effectively separate the movement of passenger cars and freight vehicles, thus reducing traffic accidents. In this study, the truck-only lane was designated in the far-right lane, and simulations were conducted as shown in Table 3 (Scenario II). However, when the truck-only lane was implemented in the fourth lane, passenger cars could merge and diverge by establishing a lane change allowance zone near the interchange. The allowance zone spanned 300 m for the exit and 150 m for the entry.

Table 3 The distribution of vehicle types per lane in each scenario

Scenario I				Scenario II			
Lane 1	Lane 2	Lane 3	Lane 4	Lane 1	Lane 2	Lane 3	Lane 4
Only passenger cars	All vehicles	All vehicles	All vehicles	Only passenger cars	All vehicles	All vehicles	Only trucks

3.4. Calibration of parameters

The simulation model parameters were calibrated to ensure that the VISSIM simulation network accurately represents the target analysis section's actual road environment and traffic flow characteristics. Table 4 provides a summary of key calibration-related data. The default parameter values were those offered by VISSIM, and the CC3 to CC9 parameters, which are difficult to observe directly, were maintained as default values. Additionally, calibration considered values recommended by the Virginia Department of Transportation [20] and the Wisconsin Department of Transportation [21]. In contrast, specific values for simulating the traffic flow of the Gyeongbu Expressway target section were calibrated and applied.

To evaluate the effectiveness of the parameter calibration, two indices were analyzed: the U-value, which assesses the similarity between the simulation network and real-world data based on speed, and the GEH (Geoffrey E. Heavers) statistic, which measures similarity based on traffic volume. The average U-value was 0.09, remaining below the threshold of 0.1, while the GEH value was 4.68, staying within the acceptable threshold of 5.0. These results confirm that the simulated traffic flow closely aligns with real-world traffic conditions in the study area.

Table 4 Parameter calibration for the preparation of the simulation

Parameters		Default value	Recommended value		Applied value	
Look ahead distance min. (m)		0.0	Typically, not modified		Basic*	225.0
					W.M.D. **	120.0
Look ahead distance max. (m)		250.0	Typically, not modified		Basic	250.0
					W.M.D.	250.0
Look ahead distance. Observed vehicles		Arterial:4 Freeway:2	4		Basic	2
					W.M.D.	4
Car following model: Wiedemann 99	Temporary lack of attention duration (s)	0.0	0.0~1.0		1.0	
	Temporary lack of attention probability (%)	0.0	0.0~5.0		5.0	
	CC0 (Standstill distance) (m)	1.5	Basic	1.22~1.68	Basic	1.4
			W.M.D.	> 1.5	W.M.D.	1.8
	CC1 (Gap time distribution) (s)	0.9	Basic	0.7~3.0	Basic	0.7~3.0
			W.M.D.	0.9~3.0	W.M.D.	0.9~3.0
	CC2 (Following variation) (m)	4.0	Basic	2.0~7.0	Basic	2.0
			W.M.D.	4.0~12.0	W.M.D.	4.0
Lane change	General behavior	Free lane selection	Free lane selection or slow lane rule		Basic	Free
					W.M.D.	Slow
	Max. deceleration - own (m/s^2)	-4.0	-4.57~-3.66		Basic	-4.0
					W.M.D.	-4.0
	$-1m/s^2$ per distance - own (m)	200.0	100.0~250.0		Basic	200.0
					W.M.D.	200.0
	Accepted deceleration - own (m/s^2)	-1.0	-0.76~-1.22		Basic	-2.5
					W.M.D.	-1.0
	Max. deceleration - trailing (m/s^2)	-3.0	-3.66~-2.44		Basic	-3.6
					W.M.D.	-3.0
	$-1m/s^2$ per distance - trailing (m)	200.0	50.0~250.0		Basic	200.0
					W.M.D.	200.0
	Accepted deceleration - trailing (m/s^2)	Arterial: -1.0 Freeway: -0.5	-0.46~-0.76		Basic	-1.5
					W.M.D.	-0.5
	Waiting time before diffusion (s)	60.0	99,999.0		99,999.0	

Note: Basic - Basic segment, W.M.D. – Weave, Merge, and Diverge segment

4. Results and Discussion

As outlined above, micro-level traffic simulations were conducted for peak and off-peak periods on the Chilgok Mulyu–Gimcheon junction section of the Gyeongbu Expressway, the designated research area. These simulations analyzed both the current traffic conditions and the scenario involving the implementation of a dedicated truck lane. The following section provides a summary of the results.

4.1. Simulation results

This study utilized travel speed and speed standard deviation as metrics to evaluate the effectiveness of the truck-only lane. According to a previously conducted study, when the speed deviation exceeds 10 km/h, there is a significant increase in the accident rate [22]. Additionally, it was found that a 1 mi/h increase in speed standard deviation corresponds to an approximately 8% increase in the likelihood of traffic accidents [23]. Based on these findings, analyzing speed deviation was hypothesized to assess driving safety effectively.

Table 5 illustrates the differences in average speed across various scenarios. During period 1, a slight decrease in average driving speed was observed in the truck-only lane compared to the current conditions, although certain sections experienced an increase in speed. In period 2, there was an average speed reduction of approximately 3.2 km/h compared to the current condition, with this decrease occurring in most sections (refer to Fig. 3).

Table 5 Comparison of travel speeds and standard deviations across scenarios (km/h)

Classification			Mean speed		Speed standard deviation	
			Average	Four lane average	Average	Four lane average
Period 1	Scenario I-1	Lane 1-3	100.9	99.1	10.5	11.7
		Lane 4	93.5		13.3	
	Scenario II-1	Lane 1-3	100.2	98.8	9.4	10.6
		Lane 4	88.4		4.4	
	Increments	Lane 1-3	- 0.7	- 0.3	- 1.1	- 1.1
		Lane 4	- 5.1		- 8.9	
Period 2	Scenario I-2	Lane 1-3	105.2	103.9	9.0	9.7
		Lane 4	102.2		10.6	
	Scenario II-2	Lane 1-3	100.7	100.7	10.3	11.5
		Lane 4	90.4		4.9	
	Increments	Lane 1-3	- 3.0	- 3.2	1.3	1.7
		Lane 4	- 10.3		- 5.7	

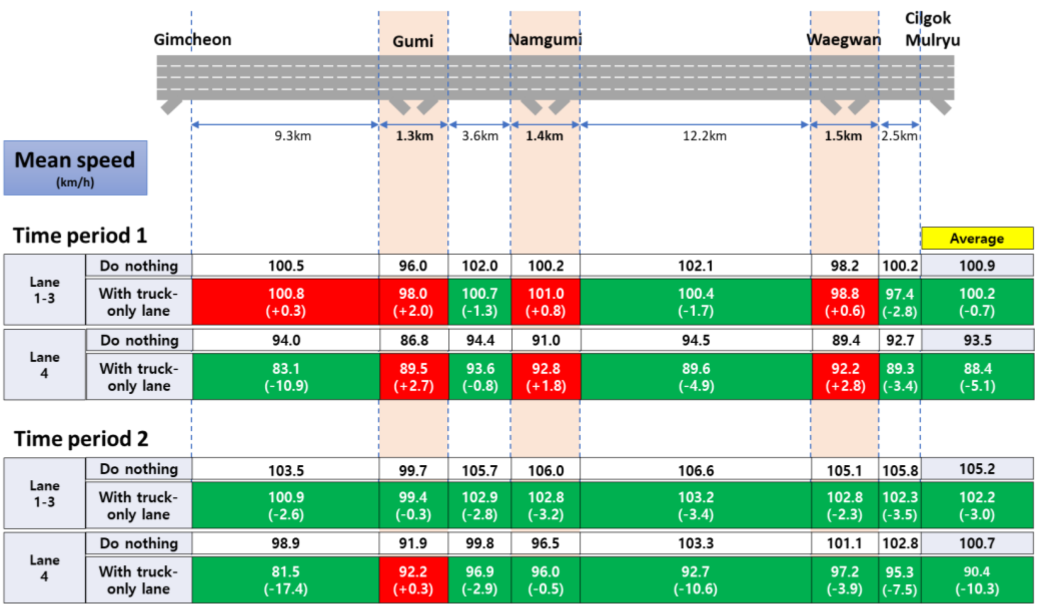

Fig. 3 Comparison of sectional travel speeds across scenarios (km/h)

The standard deviations of speed across different scenarios are presented in the last two columns of Table 5. In period 1, a comparison of the speed standard deviation for each scenario showed a decrease in the dedicated lane of 1.1 km/h for lanes 1 to 3 and 8.9 km/h for lane 4, compared to the current condition. This reduction in the speed standard deviation is significant, as research suggests that a decrease of 1 mi/h in the speed standard deviation leads to an approximately 8% decrease in accident occurrence probability, indicating a positive impact on safety. However, in period 2, with relatively lower traffic volume, there was an overall increase in the speed standard deviation in lanes 1 to 3, excluding lane 4, as shown in Fig. 4.

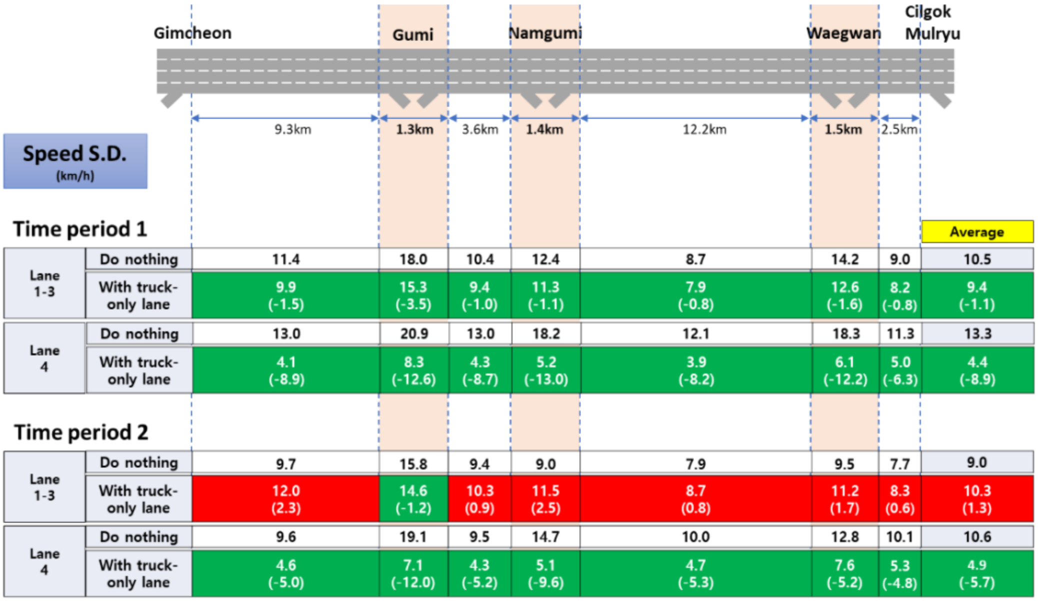

Fig. 4 Comparison of Speed Standard Deviation by Scenarios (km/h)

4.2. Discussions

Below is a summary of the findings from the analysis conducted on the effects of truck-only lane operation using VISSIM. Firstly, when comparing the cases of implementation and non-implementation of exclusive lanes, overall vehicle travel speed decreased slightly. Period 2, with a relatively lower traffic volume, showed a more significant speed reduction.

Secondly, in period 1, a decrease in the speed standard deviation was observed across all lanes, whereas in period 2, an increase was noted.

Thirdly, upon further analysis of the simulation results, it was pointed out that during period 2, the implementation of the truck-only lane led to a substantial decrease in the number of trucks utilizing the fourth lane, reducing it from 370 to 179. Relatively lower traffic volume in the adjacent lanes appeared to prompt freight vehicles to change from lane 4 to lanes 1 to 3. These lane changes were interpreted as an attempt to increase flexibility in selecting travel speeds, leading to the observed increase in the speed standard deviation.

Lastly, when a dedicated lane was introduced in the fourth lane, there were concerns about potential conflicts between passenger cars and freight vehicles entering and exiting the interchange. However, it was later confirmed that the exclusive lane arrangement had no additional impact on the conflicting traffic flow problem. This was supported by a decrease in the speed standard deviation across the entire section, even in period 1, which had high traffic volume.

As a result, implementing exclusive truck lanes decreased average driving speed and the speed standard deviation, which can impact traffic safety. However, it was observed that the driving of trucks in the fourth lane was reduced under low traffic volume conditions, which hurt the measures. These findings highlight the need for flexible operation to avoid times of low traffic when operating truck-only lanes.

5. Conclusions

This study assessed the feasibility of implementing exclusive truck lanes on Korean expressways to enhance traffic efficiency and safety by mitigating operational disparities between freight vehicles and passenger cars. A 33.2 km segment of the Gyeongbu Expressway was selected as a case study, and traffic conditions were analyzed using VISSIM under peak and off-peak scenarios with and without dedicated truck lanes. While average speeds remained largely consistent, the simulations substantially reduced speed variability, indicating improved traffic flow stability. A practical methodology was also proposed for identifying optimal segments for exclusive truck lanes, based on lane configuration, truck volume ratio, and interchange spacing. Based on the findings, the principal conclusions are as follows:

(1) Introducing exclusive truck lanes enhances traffic stability by reducing speed deviations, even without significant changes in average travel speed.
(2) The proposed segment selection methodology provides a systematic and transferable framework, with far-right lane placement preferred following domestic regulations and global best practices.
(3) Public acceptance is critical, particularly from passenger car users, as exclusive lanes may be perceived as limiting general lane access and mobility.
(4) Exclusive truck lanes should be incorporated into existing expressway systems and proactively planned in future infrastructure, including dedicated freight corridors linked to major logistics facilities.
(5) Positioning truck-only lanes on the rightmost lane can reduce merging conflicts, provided that interchange areas are designed to separate vehicle types effectively.
(6) Although differences in traffic flow based on propulsion type were not measurable, the growing share of electric trucks underscores the need to explore ICT-enabled platooning and designated electric truck corridors.
(7) Future evaluations should include advanced safety metrics such as time-to-collision (TTC) and conflict point analysis to more rigorously assess crash risk.
(8) A comprehensive assessment should also consider broader operational and environmental indicators, including travel time, delay, emissions, and projected increases in freight traffic associated with exclusive lane implementation.

List of Abbreviations

VISSIM	Verkehr In Städten – SIMulationsmodell (German for "Traffic in cities - simulation model")
LOS	Level of Service
Caltrans	California Department of Transportation
FDOT	Florida Department of Transportation
HOV	High Occupancy Vehicles
FHWA	Federal Highway Administration
LCV	Longer Combination Vehicles
STT	Single-Trailer Trucks
IC	Interchange
JCT	Junction
ICT	Information and Communication Technology

Conflicts of Interest

The authors declare no conflict of interest.

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