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Association between traffic inflow and COVID-19 prevalence at the provincial level in South Korea

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ABSTRACT

Objectives: To analyze the relationship between traffic inflow and COVID-19 prevalence in South Korea for formulating prevention policies for novel infections.
Methods: We evaluated traffic inflow and new COVID-19 cases in 8 regions of Korea from January 1, 2020, to January 31, 2021. The toll collection system (TCS) traffic volume for 2019–2020 and traffic inflow trends were analyzed using independent samples t-test and nonlinear regression, respectively. The association between TCS traffic volume and new COVID-19 cases by city was analyzed using correlation analysis.
Results: Traffic inflow volume in 2020 decreased 3.7% from 2019. The TCS traffic inflow trend in the 8 provinces decreased during the first COVID-19 wave, gradually increased until the second wave, decreased after the second wave, and showed a sharp decrease in the third wave. There was a positive correlation between the traffic inflow volume and new cases in Busan-Gyeongnam and Jeonbuk, but not in Daegu-Gyeongbuk or Gangwon.
Conclusions: A decrease in new COVID-19 cases in the regions was associated with increased traffic inflow volume. Therefore, the Korean government can establish preventive social distancing policies by identifying increases or decreases in traffic volume. These policies will also need to consider the distribution of vaccines in each area.

Introduction

In December 2019, the first case of COVID-19 was reported in Wuhan, China. Seventy-one days after the outbreak, the World Health Organization (WHO) officially declared it a pandemic (Cucinotta and Vanelli, 2020). Since then, the disease has spread to 220 countries, with 117,808,588 confirmed cases and 2,613,187 deaths as of March 9, 2021 (WHO, 2021). Therefore, several countries have banned contact between neighboring cities through city blockades to reduce contact among citizens and prevent the spread of COVID-19 (Kinross et al., 2020; Lin et al., 2021).

In Korea, the first COVID-19 case was confirmed in January 2020, and 3 major outbreak waves occurred. The first wave occurred from February 18 to March 3, 2020; it was centered in Daegu, and the lead cause was the movement to and from other regions for religious activities. The second and third waves occurred from August to September and November to December 2020, respectively. Intercity movement from other areas was highlighted as one of the causes of direct and indirect disease transmission (Lee et al., 2021).

The total population of Korea is 51.8 million, and approximately 25.96 million (50.1%) live and reside in metropolitan areas (Ministry of Public Administration and Security, 2021). Of all confirmed COVID-19 cases in Korea, 62.8% occurred in metropolitan areas, and the lead cause of cases was the high population density and the large floating population during commuting hours (Choi and Ki, 2020). Korea comprises 16 provinces, and a study reported that population movements from metropolitan areas to other regions average over 20 million per month, leading to a high risk of COVID-19 spread to those regions (Lee et al., 2020). Another study reported movement between countries and cities as the lead cause of the spread of new mutations of the virus to local communities, and that the incidence of cases in these communities is expected to rise if the inflow from other cities is not controlled (McCall, 2020).

Notably, the floating population increased in Korea as traffic volume gradually increased after the first COVID-19 outbreak in

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February 2020. It was predicted that more outbreaks would occur due to this, and the second and third waves followed (Strzelecki, 2020). A previous study identified a strong correlation between infectious diseases and traffic volume over 10 years and that the transmission of infectious diseases expands as traffic volume increases (Meloni et al., 2009). Another analysis showed that the transmission routes of 10 types of influenza occurring over the past 300 years seemed strongly related to the increase in the floating population due to the development of transportation. Similarly, coronavirus, which can spread throughout the world in a single day, is closely related to the development of transportation (Wu et al., 2019).

Our study aimed to identify the trend of traffic inflow from other cities and provinces in Korea and investigate the relationship between the traffic inflow volumes from other areas and new COVID-19 cases. Additionally, the study aimed to provide the evidence necessary to create a prevention policy to control future outbreaks of new infectious diseases.

Methods

Study design

This quasi-experimental serial study analyzed the relationship between new COVID-19 cases and traffic inflow volume to cities and provinces from other areas over 13 months from January 2020, when the first case appeared in Korea. The study was conducted using data from January 1, 2020, to January 31, 2021. The traffic inflow volume in 2020 was compared with that on the same days from January 1, 2019, to December 31, 2019, to analyze the changes in traffic inflow volume. Ethical approval and informed consent were not required for this study.

Data source

Secondary data provided by the Korea Expressway Corporation and the Centers for Disease Control and Prevention were used to measure the amount of traffic inflow from other regions at the city and provincial levels (http://data.ex.co.kr/portal/fdwn/view?type=TCS&num=C5&requestfrom=dataset#). Additionally, a data set of newly confirmed COVID-19 patients at the city and provincial levels was established using public data released by the Korea Disease Control and Prevention Agency (KCDC) (https://www.cdc.go.kr/board/board.es?mid=a30402000000&bid=0030).

The Korea Expressway Corporation's toll collection system (TCS) facilities for expressway tolls are installed in 351 toll gates across the country. According to the national transportation database (https://www.kotsa.or.kr/ptc/) from the Korea Transportation Safety Authority, 90% of the travelling population from other regions (cities) moved by private vehicle. Therefore, this study selected to use the expressway toll gates data. The Korea Expressway Corporation counts vehicles passing through the expressway toll gates daily. The cities and districts classified by the National Statistical Office of the Republic of Korea were organized into a total of 8 regions for this study: the metropolitan area (including Seoul), Gangwon- do, Daejeon-Chungnam, Gwangju-Jeonnam, Daegu-Gyeongbuk, Busan-Gyeongnam, Jeonbuk, and Chungbuk. As an example, Figure 1 shows the Seoul expressway TCS of the Korea Expressway Corporation.

The trend of new COVID-19 cases in Korea was analyzed by constructing a data set of these 8 regions based on the number of new cases per day provided by the KCDC. Information on new COVID-19 cases by region was obtained from the websites of each city, province, or *gun* office, and a data set suitable for the study was established. The number of newly confirmed patients was analyzed by assuming that they were infected 5 days previously, considering the 5-day incubation period after infection.

Statistical analysis

The relationship between traffic inflow volume from other areas and new COVID-19 cases was statistically analyzed. First, to compare the inflow from other areas between 2019 and 2020, the TCS traffic volume was calculated and compared on a monthly basis. Because the traffic volume entering cities and provinces showed a strong autocorrelation with the COVID-19 outbreak, the analysis was performed in 1-month units to minimize this autocorrelation. The formula used to calculate the difference in the TCS traffic volume between 2019 and 2020 is shown below. The significance of the difference was tested using an independent samples t-test.

$$Gap = (TCS\ Traffic\ per\ month\ in\ 2019) - (TCS\ Traffic\ per\ month\ in\ 2020)$$

Second, to analyze the trend of TCS traffic inflow from other cities and provinces in 2020, a nonlinear regression analysis was used to analyze the trends that change with time (date). Additionally, the trend of COVID-19 was analyzed based on the number of newly confirmed cases daily per city and region.

Third, Pearson's correlation analysis was conducted to analyze the correlation between traffic inflow from other cities and provinces and newly confirmed COVID-19 cases by cities and region after 5 days.

Results

Traffic inflow volume from other cities and provinces

This study analyzed the trend of traffic inflow volume from other areas from January 2020, when the first COVID-19 case was

Figure 1. Seoul expressway toll collection system of the Korea Expressway Corporation.

Table 1
Amount of traffic inflow from other areas in 2019 and 2020.

Region	Year	Traffic inflow volume from other areas												
		Month												Total
			1st Wave					2nd Wave				3rd Wave		
		1	2	3	4	5	6	7	8	9	10	11	12	
Metropolitan area	2019	20,326,828	17,470,373	21,181,843	21,224,472	21,897,092	20,761,131	21,291,156	21,186,924	20,825,331	22,971,810	21,235,806	20,507,585	250,880,351
	2020	19,762,243	18,975,046	19,291,397	19,874,917	20,924,302	20,999,518	21,458,646	19,851,326	20,377,897	21,399,922	20,607,842	19,267,859	242,790,915
	Gap	564,585	−1,504,673	1,890,446[b]	1,349,555	972,790	−238,387	−167,490	1,335,598[a]	447,434	1,571,888	627,964	1,239,726	8,089,436
Gangwon-do	2019	5,066,197	4,624,583	5,214,687	5,189,970	5,705,962	5,306,084	5,435,389	6,173,517	5,137,656	5,856,471	5,536,166	5,294,537	64,541,219
	2020	5,195,563	4,156,189	4,484,531	4,918,493	5,326,005	5,348,162	5,530,151	5,539,628	5,090,533	5,800,919	5,192,656	4,636,786	61,219,616
	Gap	−129,366	468,394	730,156[c]	271,477	379,957[a]	−42,078	−94,762	633,889[c]	47,123	55,553	343,510[a]	657,751[c]	3,321,604[c]
Daejeon- Chungnam	2019	7,269,926	6,622,336	7,782,188	7,926,977	8,273,724	7,340,439	6,917,105	7,740,111	6,782,219	7,903,222	8,494,302	7,967,995	91,020,544
	2020	7,664,574	6,353,593	6,982,367	7,676,948	8,538,223	8,266,710	8,140,495	8,008,638	8,150,617	8,825,928	8,482,733	7,607,824	94,698,650
	Gap	−394,648[a]	268,743	799,821[c]	250,029	−264,499	−926,271[c]	−1,223,390[c]	−268,527	−1,368,398[c]	−922,706[a]	11,569	360,171	−3,678,106[c]
Gwangju- Jeonnam	2019	5,795,463	5,962,106	6,719,344	6,567,490	6,961,475	6,432,183	6,338,971	7,121,344	6,365,976	6,917,991	7,282,472	7,267,878	79,732,693
	2020	6,710,985	5,402,025	6,031,806	6,253,246	7,105,194	6,696,180	6,309,537	7,060,102	6,570,910	7,519,637	6,884,574	6,298,080	78,842,276
	Gap	−915,522[b]	560,081	687,538[c]	314,244	−143,719	−263,997	29,434	61,242	−204,934	−601,646[a]	397,898	969,798[a]	890,418
Daegu-Gyeongbuk	2019	8,953,781	8,473,941	9,630,197	9,605,872	10,120,300	9,553,464	9,531,637	9,772,372	9,354,940	10,821,278	10,069,020	9,569,958	115,456,760
	2020	9,301,374	7,299,451	7,322,354	8,465,979	9,478,570	9,108,944	9,217,520	9,491,002	9,251,505	9,975,058	9,562,928	8,817,864	107,292,549
	Gap	−347,593	1,174,490[b]	2,307,843[c]	1,139,893[a]	641,730[b]	444,520	314,117	281,370	103,435	846,221	506,092[b]	752,094[c]	8,164,212[c]
Busan- Gyeongnam	2019	15,772,130	14,684,595	16,675,549	16,549,223	17,176,180	16,181,813	16,614,166	17,366,757	16,026,642	17,218,413	17,143,159	16,733,522	198,142,149
	2020	16,183,814	13,520,714	14,346,308	15,063,522	16,614,004	15,303,715	15,325,665	15,567,865	14,928,544	16,179,028	15,704,433	14,992,034	183,729,646
	Gap	−411,684	1,163,881	2,329,241[c]	1,485,701	562,176	878,098	1,288,501[c]	1,798,892[c]	1,098,098	1,039,386[b]	1,438,726[c]	1,741,488[c]	14,412,504[c]
Jeonbuk	2019	2,839,163	2,791,114	3,097,900	3,151,561	3,395,215	3,158,013	3,193,316	3,623,271	3,322,050	3,504,732	3,462,673	3,088,032	38,627,040
	2020	3,088,368	2,326,024	2,601,619	2,907,981	3,312,554	3,128,643	3,086,169	3,306,517	3,225,624	3,590,666	3,336,586	2,856,045	36,766,796
	Gap	−249,205	465,090[b]	496,281[c]	243,580	82,661	29,370	107,147	316,754[b]	96,426	−85,934	126,087	231,987[b]	1,860,244
Chungbuk	2019	3,846,413	3,658,044	4,221,580	4,396,684	4,332,408	4,036,991	3,840,366	4,300,431	3,766,705	4,670,264	4,584,027	4,092,664	49,746,577
	2020	4,042,632	3,218,638	3,511,899	3,978,325	4,413,397	4,394,541	4,344,766	4,216,102	4,231,051	4,631,953	4,385,094	3,724,119	49,092,517
	Gap	−196,219	439,406	709,681[c]	418,359	−80,989	−357,550[a]	−504,400[c]	84,329	−464,346[b]	38,311	198,933	368,545[b]	654,060

1) Gap = (TCS Traffic per month in 2019) − (TCS Traffic per month in 2020).
1st wave: February 1–March 31, 2020 (Peak date: March 3).
2nd wave: August 1–September 31, 2020 (Peak date: August 26).
3rd wave: November 1–December 31, 2020 (Peak date: December 24).
TCS, toll collection system.
[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.001$.

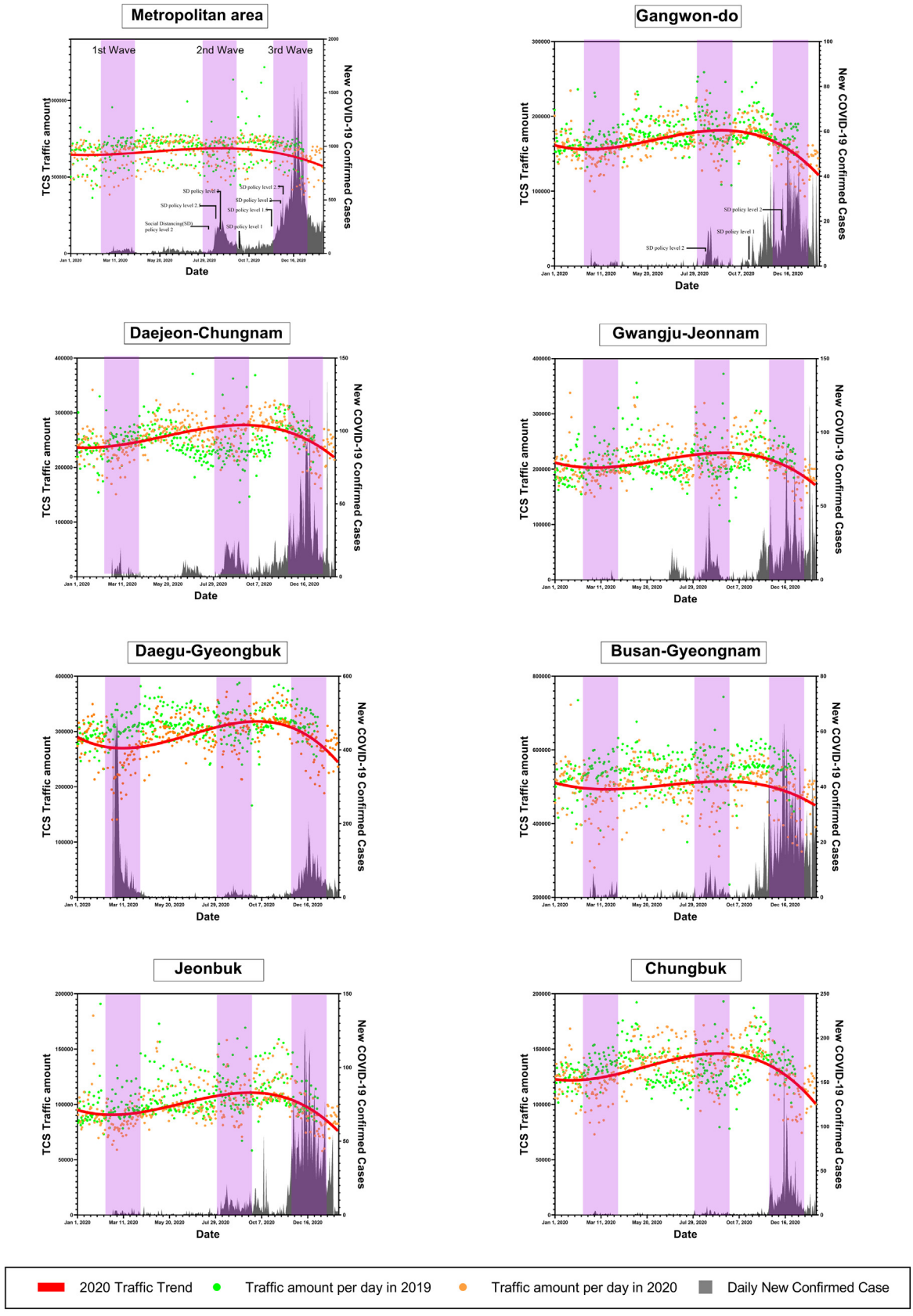

Figure 2. Trends in traffic inflow volume and new coronavirus disease cases by city and province in 2019 and 2020.
TCS traffic trend curve in 2020 is represented by a red line on the left Y-axis. Daily new COVID-19 confirmed cases are marked on the right Y-axis. Daily new COVID-19 confirmed cases are confirmed patients who were infected 5 days previously, considering the incubation period after infection. Traffic inflow volume from other areas in 2019 and 2020 is indicated by green dots for 2019 and orange dots for 2020. First, second, and third waves of outbreaks in Korea are indicated by a vertical dotted line. (TCS, toll collection system; COVID-19, coronavirus disease).

confirmed in Korea, until January 2021. Data from toll gates on expressways were used to analyze the traffic inflow from other cities and provinces. The data were compared with 2019 data to establish the trend of traffic inflow in 2020, using t-tests for the analysis (Table 1).

The traffic inflow volume from other areas into the 8 regions was analyzed using the TCS traffic volume data. As compared to 2019, the amount of traffic inflow from other areas had reduced in 2020 in 7 regions, with a significant decrease observed in the regions of Gangwon-do (3,321,604; $P < 0.001$), Daegu-Gyeongbuk (8,164,212; $P < 0.001$), and Busan-Gyeongnam (14,412,504; $P < 0.001$). Conversely, there was a significant increase in Daejeon-Chungnam in 2020 (3,678,106) when compared with 2019 ($P < 0.001$).

In analysis of cities and provinces showing significant changes in the TCS traffic volume in 2020, the inflow volume was observed to have decreased significantly in all 8 regions in March 2020. Furthermore, 4 regions showed a significant decrease in August 2020, and 6 regions showed a significant decrease in December 2020.

Significate change in the TCS traffic inflow volume was observed in the 8 regions as follows: metropolitan area decreased significantly in 2 months (March and August); Daejeon-Chungnam increased significantly in 6 months (January, June, July, August, September, and October), with a significant decrease in 1 month (March); Chungbuk, increased significantly in 3 months (June, July, and September), while 2 months (March and December) showed a significant decrease; Gangwon-do decreased significantly for 5 months (March, May, August, November, and December); Daegu-Gyeongbuk decreased significantly for 6 months (February, March, April, May, November, and December).

Trends of traffic inflow volume from other cities and provinces and new COVID-19 cases

Figure 2 shows the traffic inflow volume to the 8 regions, new COVID-19 cases, and the KCDC-implemented social distancing level (Levels 1, 1.5, 2, 2.5 and 3) by region. Traffic volume data from other cities and provinces in Korea showed that traffic volume in 2020 had decreased in each region compared with 2019. Notably, the amount of traffic inflow from outside decreased compared with volumes in the year before, in all 8 regions after January 19 2020, when the first COVID-19 case was confirmed in Korea. There was a further sharp decrease in the traffic inflow volume in March when the first wave occurred. In particular, traffic inflow volume in Daegu-Gyeongbuk, the main region of the first wave, declined sharply in March. After the first wave, traffic inflow volume in the 8 regions continued to increase. There was then a sharp decrease in traffic inflow volume from September, the second wave, until December, the third wave.

The analysis of the trend in the TCS traffic volume in the 8 regions and of new COVID-19 cases showed that newly confirmed cases increased when TCS traffic inflow volume decreased in the first wave of the outbreak. In the second wave, newly confirmed cases increased as TCS traffic inflow volume increased. In the third wave, the TCS traffic volume trend decreased while newly confirmed cases increased.

In comparing the width of the trend curve of traffic volume by region, the traffic inflow volume trend in the metropolitan area was slight, but it showed a decrease in the third wave. Traffic inflow volume in Daegu-Gyeongbuk, where the first wave occurred, declined substantially in March; however, it sharply increased in the second wave, followed by a sharp decrease in the third wave.

Correlation between traffic volume from other areas and new COVID-19 cases by region in 2020

A correlation analysis was conducted to examine the relationship between traffic volume from other areas and new COVID-19 cases in 2020 in the 8 regions analyzed in this study. The results showed a correlation between the traffic inflow volume and newly confirmed cases in 5 regions, namely Gangwon-do, Gwangju-Jeonnam, Daegu-Gyeongbuk, Busan-Gyeongnam, and Jeonbuk. Notably, 3 regions showed a negative correlation between traffic volume and new COVID-19 cases during 2020: Daegu-Gyeongbuk ($r = -0.0188$, $P < 0.001$), Gangwon-do ($r = -0.156$, $P < 0.001$), and Gwangju-Jeonnam ($r = -0.099$, $P = 0.004$). On the other hand, Busan-Gyeongnam ($r = 0.328$, $P < 0.001$) and Jeonbuk ($r = 0.325$, $P < 0.001$) showed a positive correlation.

Similarly, a correlation coefficient analysis was conducted between the traffic volume from other areas and new COVID-19 cases for the first, second, and third waves in Korea. In the first wave, the metropolitan area showed a significant positive correlation ($r = 0.019$, $P = 0.038$), while Daegu-Gyeongbuk showed a significant negative correlation ($r = -0.355$, $P = 0.003$). In the second wave, the metropolitan area, Gwangju- Jeonnam, Daegu-Gyeongbuk, and Busan-Gyeongnam showed significant negative correlations. All 8 regions showed a negative correlation between traffic inflow volume and new COVID-19 cases in the third wave.

Discussion

This study analyzed the correlation between traffic inflow volume from other areas and new COVID-19 cases in 8 regions.

After the first confirmed case of COVID-19 in Korea on January 19, there were 3 waves of outbreak in March, August, and December 2020 (Seong et al., 2021). Traffic inflow to the 8 regions decreased in 2020 compared with 2019 in all but 1 region (Daejeon-Chungnam). This finding is consistent with a previous study that reported that an increase in cases of a new disease leads to a decrease in external activities (Slimani et al., 2020). It is also consistent with another study that investigated the relationship between COVID-19 and traffic volumes (Lee et al., 2020). Previous studies on COVID-19 analyzed factors such as the Korean government's reinforcement of regulations, including refraining from transportation using vehicles, limiting seats on public transportation, reducing the amount of transportation, and social distancing policies, which affected movement between cities (Park et al., 2020a,b). In Korea, citizens voluntarily refrained from leaving home and practiced social distancing, despite the country never implementing a lockdown as other countries had (Ghosal et al., 2020; Kim et al., 2020). The decrease in traffic inflow volume to the regions identified in this study is indicative of this behavior. On the other hand, the amount of traffic flowing into Daejeon-Chungnam increased, probably because only 1.6% of all confirmed cases occurred there as of March 5, 2021. Therefore, it is assumed that citizens entered Daejeon-Chungnam with less fear than other regions (CoronaBoard, 2021).

Figure 2 shows the correlation between traffic volumes from other areas and new COVID-19 cases in the 8 regions over the 3 waves of outbreak. The first wave started in Daegu on February 18 and reached its peak on March 3 (Daegu Metropolitan City, 2020). There was a maximum of 741 cases per day and 6144 cumulative cases in the month of the first wave, resulting in issues such as a shortage of hospital rooms (Yonhap News TV, 2021). This first wave occurred because the 31st COVID-19 patient from Seoul moved to Daegu. Hence, movement between cities and provinces was the primary cause of COVID-19 spread. Accordingly, the Korean government attempted to reduce the movement of citizens through policies such as refraining from traveling, working from home, delaying the opening of elementary, middle, and high schools, and conducting online university classes (National Research Council for Economics & Humanities and Social Sciences, 2020). As evidenced by the results of this study, the traffic volume decreased significantly in March 2020 compared with 2019 in all 8

regions. However, the traffic volume decreased significantly in only 4 regions during the second wave and increased in Daejeon-Chungnam. According to previous studies, citizens' perceived risk regarding a new disease reduces when its spread in the community lasts for 3 months. A study on COVID-19 reported a similar reduction in perceived risk (Lalot et al., 2020). Additionally, data showed that numerous citizens traveled during the Chuseok public holiday despite the government's recommendation to refrain from traveling; 90% of the people used their own vehicles to travel, unlike in 2019, thus increasing traffic inflow to other cities (Korea Expressway Corporation, 2020).

In the third wave of outbreak, there was a significant decrease in the traffic volume across 6 regions. The main cause of the third wave was presumed to be the linkage with secondary transmission and transmission through patients with mild or no symptoms in the community (Central Disaster and Safety Countermeasures Headquarters, 2020). During the third wave, only 6 of the 8 regions showed significant differences in traffic inflow volume compared with 2019. However, the peak day of the third wave was December 24, as movement increased slightly during Christmas, which may have induced the largest number of new cases.

This study analyzed the correlation between traffic volumes from other cities and provinces and new COVID-19 cases. The volume trend was analyzed using nonlinear regression analysis. The findings regarding the correlation between traffic volumes from other cities and provinces and new COVID-19 cases were as follows: 1) a decrease in traffic to and from other areas after the first wave; 2) a decrease in traffic inflow between cities and provinces with an increase in the number of new cases; 3) contradictory correlations between cities and provinces.

First, the traffic volume continuously increased after the first wave across the 8 regions. This increase may have been due to deregulation by the government as well as citizens' complacency when the number of new COVID-19 cases showed a declining trend. There was a sharp decrease in traffic volume in all 8 regions after the second wave of the outbreak. This was after the Korean government announced social distancing guidelines, which were systematized into 3 levels after the second wave, and this is believed to be because of the reorganization into 5 levels after November 7. However, analysis of the first wave of the outbreak using Korea's national traffic volume data showed that traffic volume and the number of newly confirmed cases were negatively correlated, except in the metropolitan area. On the other hand, the analysis over 1 year showed that 5 out of 8 regions had a negative correlation, including the metropolitan area (Lee et al., 2020).

Second, analysis of volume of traffic inflow and new COVID-19 cases revealed a positive correlation during the first wave in the metropolitan area. Four regions showed significant negative correlations during the second wave and all 8 regions during the third wave, indicating that people were reluctant to enter areas with many confirmed cases (Neuburger and Egger, 2020). These results indirectly show that as the number of newly confirmed cases in the country increased, psychological factors and the reinforcing of national social distancing and working from home policies were effective in reducing traffic.

Third, among the regions with significant correlations between traffic inflow volume and new COVID-19 cases, Busan-Gyeongnam and Jeonbuk showed positive correlations while Daegu-Gyeongbuk and Gangwon-do showed negative correlations. In Busan-Gyeongnam and Jeonbuk, the number of confirmed cases increased when traffic inflow volume increased. The cause of transmission in these 2 regions was a 'super-spreader' from a different area (Busan Metropolitan City, 2021; News1 Korea, 2020; Kyeongnam News, 2021). In contrast, Daegu, Gyeongbuk, and Gangwon showed negative correlations, which could be because Daegu-Gyeongbuk was the lodgment region for the first wave, so citizens did not visit. Daegu was temporarily closed, and movement from outside was restricted as an outbreak had occurred there. The main reasons for inflow to Gangwon-do were tourism, business, and visits to elderly parents. Accordingly, if the number of confirmed cases increased in Gangwon-do, tourism, business trips, and visits to elderly parents were bound to reduce (Tables 2 and 3).

This study had several limitations. First, only the amount of movement indirectly available through the TCS traffic volume of

Table 2
Correlation between traffic volume from other areas and new cases of COVID-19 by region.

	1st wave		2nd wave		3rd wave		Total	
	r	*p*	r	*p*	r	*p*	r	*p*
Metropolitan area	0.190	0.038[a]	−0.207	0.026[a]	−0.432	<0.001[c]	−0.006	0.429
Gangwon-do	−0.120	0.125	−0.070	0.233	−0.306	<0.001[c]	−0.156	<0.001[b]
Daejeon- Chungnam	−0.045	0.322	−0.021	0.406	−0.434	<0.001[c]	0.031	0.194
Gwangju- Jeonnam	0.130	0.160	−0.488	<0.001[c]	−0.341	<0.001[c]	−0.099	0.004[b]
Daegu-Gyeongbuk	−0.355	0.003[b]	−0.177	0.025[a]	−0.639	<0.001[c]	−0.188	<0.001[c]
Busan- Gyeongnam	−0.118	0.128	−0.164	0.041[a]	−0.432	<0.001[c]	0.328	<0.001[c]
Jeonbuk	0.104	0.150	0.001	0.498	−0.405	<0.001[c]	0.325	<0.001[c]
Chungbuk	−0.045	0.329	−0.021	0.414	−0.510	<0.001[c]	−0.019	0.335

1st wave: February 1–March 31, 2020 (Peak date: March 3).
2nd wave: August 1–September 31, 2020 (Peak date: August 26).
3rd wave: November 1–December 31, 2020 (Peak date: December 24).
[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.001$.

Table 3
Relationship between traffic inflow volume from other areas and new COVID-19 cases by region.

Relationship with the traffic inflow volume from other areas	Positive correlation	Negative correlation
Present[a]	Busan-Gyeongnam, Jeonbuk	Daegu-Gyeongbuk, Gangwon-do
Absent[b]	Daejeon-Chungnam	Chungbuk, Metropolitan area

[a] Significance level of the correlation coefficient ≤0.05.
[b] Significance level of the correlation coefficient >0.05.

the expressways was calculated and analyzed. Future studies will need to analyze public transport in addition to private vehicles to measure and analyze detailed movements. Second, since the analysis was conducted at the city and provincial levels, it will be necessary to analyze towns and districts and examine the associations in these areas. Third, non-COVID-19 related factors influencing travel such as temperature, environment and economics were not considered. This study was conducted using only TCS traffic volume. In a future study, confounding factors will need to be considered.

Conclusion

The traffic inflow in 2020 decreased in all 8 regions when compared with 2019. In particular, there was a trend of increasing movement between cities and provinces after the first wave in Korea. However, as the second wave occurred and the Korean government reinforced social distancing in 5 levels, traffic volume showed a steadily decreasing trend.

On examining the correlation between traffic inflow and new COVID-19 cases by region, Busan-Gyeongnam and Jeonbuk showed positive correlations; the number of new COVID-19 cases increased as the inflow from other areas increased.

The traffic inflow from other areas reduced in Daegu-Gyeongbuk and Gangwon-do when the number of new cases increased; this was mainly due to Daegu being the lodgment region of the first wave and the tourism industry in Gangwon-do.

Korea started distributing the COVID-19 vaccine from the end of February 2021 and is pursuing the goal of community immunity by the third quarter (Korea Disease Control and Prevention Agency, 2021). A change to the population entering from other areas into these 8 regions is expected once community immunity is achieved. According to the results of this study, inflow from other areas increased when the number of newly confirmed COVID-19 cases in the region decreased. Therefore, the Korean government, including the KCDC, should establish a preventive social distancing maintenance policy by identifying an increase or decrease in traffic volume. Furthermore, it will be necessary to establish a policy on social distancing with respect to traffic volume according to the distribution of vaccines by area.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical approval

Ethical approval or individual consent was not required.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2021.05.054.

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