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MOBILITY AND TRANSPORT CONNECTIVITY SERIES

# DO SPEED LIMIT REDUCTIONS HELP ROAD SAFETY?

## Lessons from the Republic of Korea's Recent Move to Lower Speed Limit on Urban Roads


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# DO SPEED LIMIT REDUCTIONS HELP ROAD SAFETY?

## Lessons from the Republic of Korea's Recent Move to Lower Speed Limit on Urban Roads

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# Contents



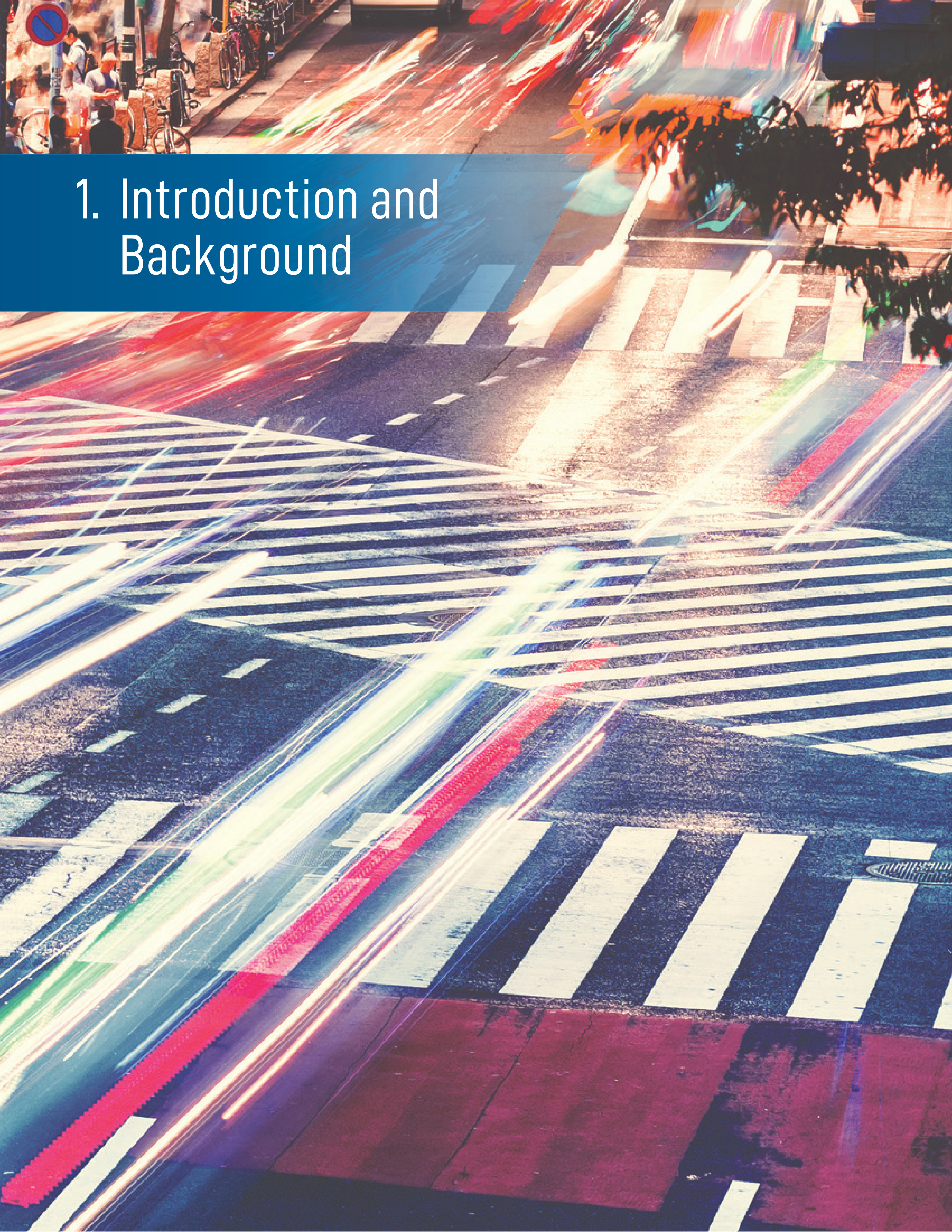
## Figures



## Tables



# 1. Introduction and Background



In many countries, speeding has become one of the most important risk factors contributing to road traffic fatalities and injuries. When vehicles are driven at high speed, the likelihood and severity of crashes increases, which leads to speed management becoming an essential tool for improving road safety (ITF 2018). An important component of speed management is setting the right speed limits, as they convey the maximum legally permissible travel speed to the road user, given the type of road, set up, and the type of road users who most often use the facility. As one of the most fundamental rules of road traffic operations, speeds greatly influence not only traffic safety and operations, but also climate impacts and air and noise pollution (Sakashita and Job 2016). By reducing the likelihood of vehicle-to-vehicle conflicts and conflicts among vehicles, cyclists, and pedestrians, an appropriate speed limit can enhance the safety of driving as well as walking, cycling, and motorbike riding. Indeed, setting safe speed limits, along with the supporting infrastructure and enforcement, is one of the most important ways to enhance traffic safety and secure the efficiency of mobility on roadways.

Many countries have established speed-limit regulations based on roadway classifications, observed traffic patterns, and the intended usage of the road (or, more appropriately, actual use of the road and surrounding land use). Yet regulatory practice varies greatly from country to country, even with compelling evidence-based support for specific optimal speed limits on a very wide range of road geometries and the surrounding conditions, such as land use, the presence of roadside objects, and users such as pedestrians, cyclists, and motorcyclists. For example, most developing countries—including many of the World Bank's client countries—lack regulations or even the criteria for determining appropriate speed limits.

In countries experiencing high motorization and development, the lack of regulations results in suboptimal speed limits for safety and mobility. For instance, according to data from the World Bank's recently published "Guide for Road Safety Opportunities and Challenges: Low- and Middle-Income Country Profiles" (Wambulwa and  Job 2020), currently very high speed limits are posted on urban roads in most low and middle-income countries (LMICs), where interactions with vulnerable road users are significant. In such environments, the recommended Safe System speed is no more than 30 kilometers per hour (kph), but no low-income countries (LICs), and only 3 percent of middle-income countries (MICs), have posted speed limits of 30 kph or less on urban roads. Yet, most of the available studies on speed regulation and management have been conducted in higher income countries such as Australia, the United States, and western  Europe. The Republic of Korea (hereinafter "Korea"), which regulates speed limits through the Road Traffic Act (specifically, Article 19 of the Enforcement Regulations), provides an example of an Asian country seeking to change and improve its road usage regulations.

In April 2016, the National Police Agency in Korea established the Transportation Infrastructure Construction Basic Plan, in which for the first time, the Safe Speed 5030 policy was included for urban pedestrian safety. For its effective implementation, subsequently, the 5030 Council was formed at the pan-governmental level, comprising the Ministry of Land, Infrastructure, and Transport (MOLIT) and relevant agencies. In the same year, the 8th National Road Safety Basic Plan was presented, acknowledging the "expanded application of urban speed limit 50/30" as an intermediate implementation measure, emphasizing the need for speed management for the achievement of the goals of transportation safety.

This was entailed, in April 2019, by an amendment to the Approved Code of Practice of the Road Traffic Act, adjusting the maximum speed to 50 kph as the standard speed limit on roads in urban areas, which is awaiting its official enforcement in 2021. In recent years the country's National Policy Agency has changed the speed limit of many urban roadways to 50 kph or 30 kph to enhance traffic safety and maintain smooth driving.

As a result of the speed limit control policy, the World Bank and other international organizations have focused on improved urban road safety in Korea, and hope to transfer the experience of the speed policy and associated best practices to other developing countries through joint research. Furthermore, lessons from an Asian country—namely, Korea—could be more acceptable to neighboring Asian countries also experiencing accelerated development and increased travel demands in urban areas.

**With this in mind, the Korea Transport Institute (KOTI) and the World Bank conducted a joint research project to assess the safety benefit of lowered speed limits on urban roads and to inform future policy development on speed limits in urban areas.** Specifically, this study analyzes how changes in the speed limit affect safety performance and operational performance. Because speed limits influence the operating speed of the facility and affect both safety and operational efficiencies, the study team hypothesized that studying the effect of *changes* in speed limit might yield valuable demonstration examples in the context of Asia and other developing countries.

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# 2. Objectives and Scope

Significant research has been undertaken on how changes in speed limit—for example, the introduction of 30 kilometers per hour, or kph (20 miles per hour, or mph) speed limits—impact safety both when combined with, and without "traffic-calming" engineering treatments such as speed humps or raised platforms. However, most of the studies have been conducted in Australia or countries in Western Europe, with almost no recorded studies from Asia, Africa, the Americas and Eastern Europe. Though it may be reasonable, a well-developed infrastructural environment such as that found in Korea would expect similar results as that of the western countries, a study originating in Asia could have a strong demonstration effect and prove very convincing for many Asian countries.

With this in mind, the main aim of this study[1] is to present the findings from Korea's reduced speed limits on safety performance and to support establishment of suitable speed-management strategies based on a quantitative data-driven approach. The scope of the project was as follows:

1. Evaluate the effectiveness of the reduced speed limits in terms of crash reduction through a before-after study.

2. Examine if the speed limit change had different effects across different crash types, user types, and crash severities.

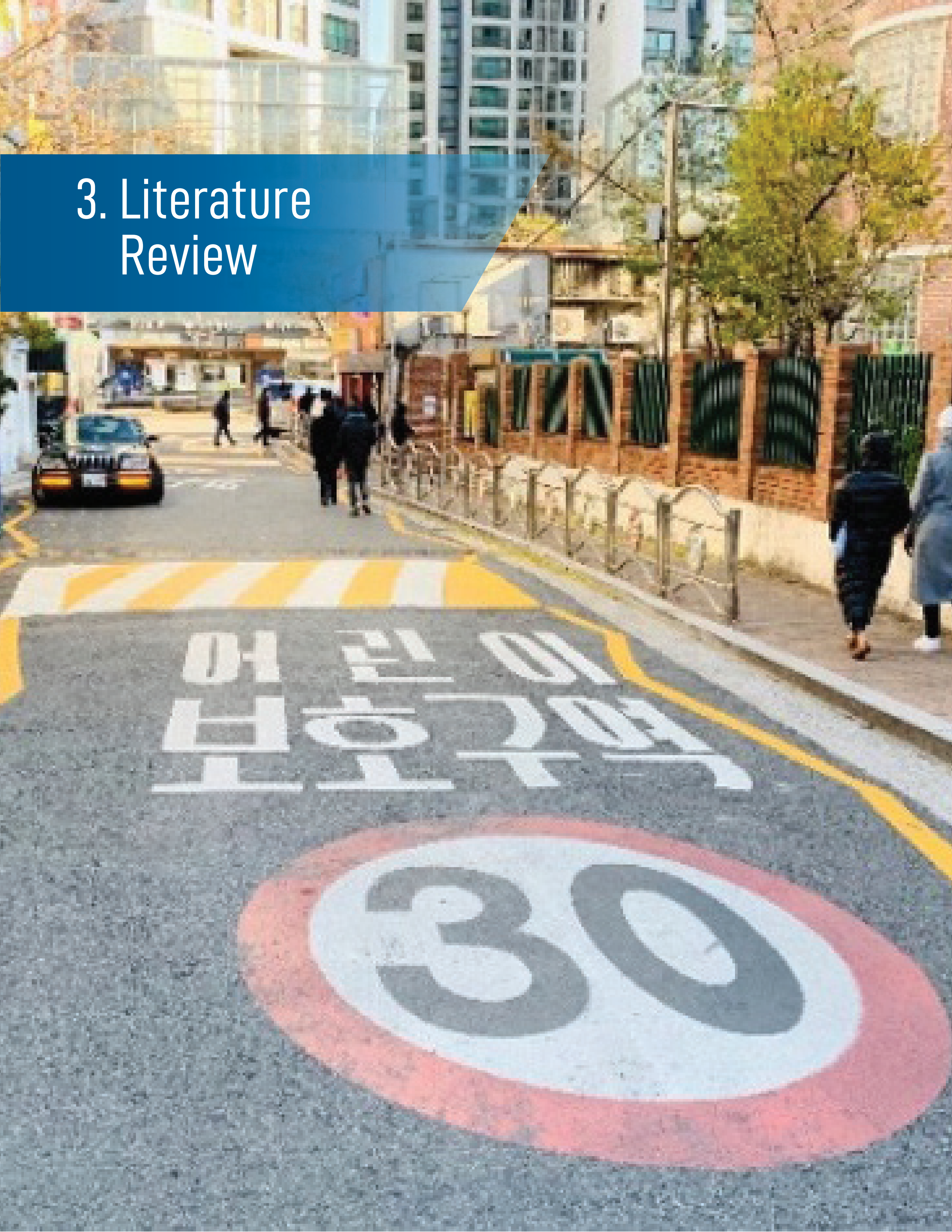
3. Evaluate the impact of speed limit change on transit speed through a before-after assessment.

4. Develop appropriate and actionable recommendations for departments of transportation in developing countries.

To start, this report first provides a brief literature review on the concept of Safe System speed limits, and the effect of speed limit reductions as part of speed management in several countries, followed by a brief description of the evaluation methods for the before-after assessment. This is followed by a summary of the findings, a set of recommendations, limitations of this study, and finally, a capsule of future research that could be undertaken to either extend or follow up on the study.

1 The study was funded by the Korea Transport Institute (KOTI). World Bank staff involvement was funded by the World Bank and the Global Road Safety Facility (GRSF), with UK Aid funding.

# 3. Literature Review



# Speed and Safety Risk

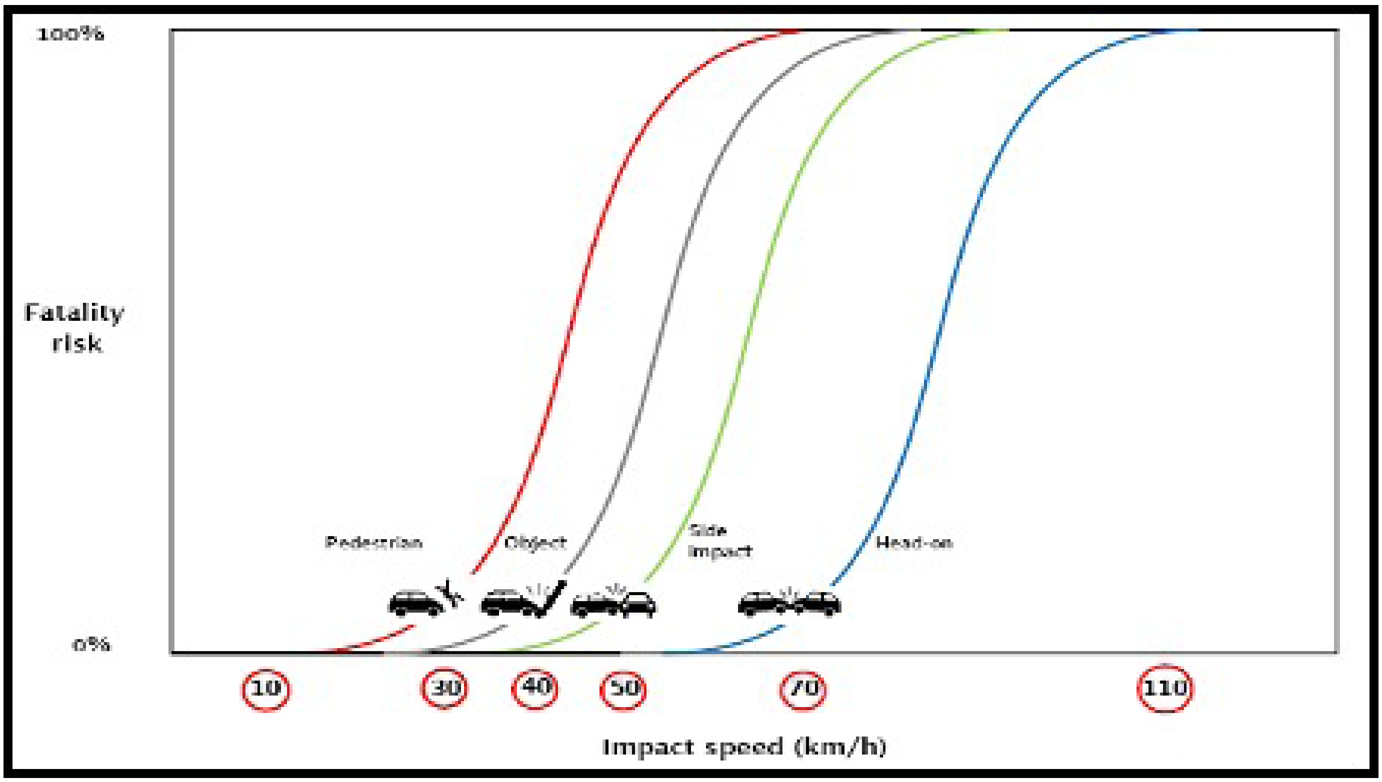
Speeding is one of the most significant risk factors for road traffic fatalities and injuries all over the world. Because driving vehicles at higher speeds increases both the likelihood and severity of crashes, speed management is recognized as an essential tool for improving road safety (ITF 2018).

Out of several different speed management methods, lowering the posted speed limit using a static sign (and enforcing that lower posted speed limit) is one of the more common, and effective, road-safety interventions. As a widely adopted speed management measure, static signage is often associated with or without other engineering measures aimed at producing lower vehicle speeds and crash and injury severity reductions.

In addition, speed management is central to the Safe System approach of road design, which views human life and health as more important than anything else. Thus, the consequences for speed management of adopting a Safe System approach result in certain maximum speed limits, which depend on the road environment and the most predominant risk in such environment. For example, a speed limit in urban built-up areas with a mix of vulnerable road users and vehicular traffic will be very different than the limit posted on urban roads with signalized intersections and limited interactions with vulnerable road users—and will vary even further from the limit on rural two-lane, undivided roads.

In urban environments in low and middle-income countries (LMICs), interactions between pedestrian and other vulnerable road users and motorized traffic is often very high, mainly in the absence of infrastructure to separate them from high speed traffic. On the other hand, side-impact crashes, are the most frequent and most severe kind of vehicle to vehicle crashes possible at urban intersections, where pedestrians and other vulnerable road users are safely separated from traffic. Likewise, head-on crashes predominate on rural two-lane undivided highways (ITF 2018). The graph in figure 3.1 shows how the risk of a fatality rises with an increase in impact speed, for four different crash types: pedestrian crashes, crashes into rigid objects, side-impact crashes, and head-on crashes.

**Figure 3.1.** How a Change in Impact Speed Changes the Risk of Fatality, by Different Crash Types




**Source:** NSW Centre for Road Safety (n.d).

Figure 3.1 clearly illustrates the dramatic effect of speed on the risk of fatality in virtually any type of crash situation. The results strongly mandate safe speed limits for different road environments, which are commonly known as Safe System speed limits. On the graph, the "Safe System speeds" are set at a point that enables a 90 percent survival rate (or 10 percent fatality rate):

- 30 kilometers per hour (kph) for impacts with pedestrians (and other vulnerable road users such as cyclists)
- 40 kph for impacts with solid objects
- 50 kph for car-on-car side-impact crashes
- 70 kph for car-on-car head-on crashes

Even these limits may be considered too high to achieve a 90 percent survival rate, not even considering the inevitably much higher rates of serious injury, more so for vulnerable road users who have no physical protection. Since creating low-speed environments to provide a greater degree of safety for vulnerable road users is one of the major aims of the speed management program, physical speed restraint measures, along with infrastructure and engineering measures, are often added to achieve higher levels of road user compliance in addition to posting lower speed limits. With this treatment, the reduction in serious injuries to pedestrians can be very high—in excess of 70 percent (Woolley et al. 2018; FHWA 2020)—with significant benefits for road users as well.

Crucially, the safety benefits of a speed limit reduction depend very much on the magnitude of the change and the level of compliance produced by both engineering and enforcement mechanisms. Speed limits exert a major influence on actual driving speeds. However, the changes in speed observed when introducing a new speed limit will rarely be strictly proportional to the change in the speed limit, as presented by Elvik (2012) based on a meta-analysis. Elvik concluded speed almost always changes in the same direction as speed limits, but in almost all cases, a reduction in the speed limit of, for example, 20 kph, would result in an approximate 8 kph change in mean traffic speed. A 10 kph reduction in the speed limit results in a much smaller change in actual traffic speeds, typically around 2.5 kph. However, the good news is that a 10 kph reduction in the speed limit could be expected to produce about a 15 percent reduction in injury crashes, and upwards of a 40 percent reduction in pedestrian fatalities and serious injuries; however, evidence shows the benefits can be even greater in the right circumstances (McTiernan et al. 2015; Turner, Howard, and Breen 2015; Jurewicz 2010; Elvik et al. 2009).

For example, two extensive studies undertaken by UK-based TRL, formerly the Transport Research Laboratory (Webster and Mackie 1996; Webster and Layfield 2003), suggest implementation of 30 kph (20 mph for the study) zones with physical traffic calming measures could result in substantial reductions in average speed of around 14 kph, or 9 miles per hour (mph), and sizeable reductions in collisions. In both studies, speeds before these schemes were introduced averaged around 40 kph (25 mph), dropping to well below 30 kph (20 mph) after implementation.

Comparison of before-after crash data from the first study, for a total of 72 schemes, showed average annual crashes fell by 60 percent, while child pedestrian and cyclist crashes fell by 70 percent and 48 percent respectively. In the second study, conducted by Webster and Layfield (2003), which looked at crash data for 78 schemes, a before-after comparison indicated a lower frequency of injury crashes within the zones by about 42 percent, and a lower frequency of fatal or serious injury (killed or seriously injured, or KSI) crashes by about 53 percent. However, results from a 2018 study evaluating the effectiveness of 20 mph (sign-only) speed limits reductions (Atkins Ltd., AECOM, and Mather 2018) in the United Kingdom was somewhat inconclusive. The study findings indicated that except in one case study location (Brighton Phase 1) evidence showed no significant short-term change in collisions and casualties. The results from the Brighton Phase 1 study, however, showed promise where a blanket 20mph limit was introduced covering both major and minor roads. In addition, data also indicated a statistically significant change in collisions and casualties relative to the 30 mph comparison group, concluding a significant reduction in overall collisions (–18 percent), overall casualties (–19 percent), pedestrian casualties (–29 percent), and casualties aged 75 or over (–51 percent). The study suggested the need for further data collection to determine the longer-term impact of 20 mph limits.

Another recent study of speed limit reduction program from the Latin American city of São Paulo, Brazil (Ang, Christensen, and Vieira 2020) also concluded the program of regulatory change in speed limit resulted in 1,889 averted crashes within the first 18 months of such change, reducing crashes by 21.7 percent on treated roads, with larger effects on roads with camera-based enforcement.

While speed limit reductions show enhanced safety outcomes, additional studies demonstrate the harm caused by speed limit increases. A study conducted by Farmer (2017) to examine the safety effects of increases in U. S. state maximum speed limits during the period from 1993 to 2013 associated a 5 mph (8 kph) increase in the maximum state speed limit with an 8 percent increase in fatality rates on interstates and freeways, and a 4 percent increase on other roads. In total, an estimated 33,000 more traffic fatalities occurred than would have been expected with the lower speed limits.

Another study from Victoria, Australia (Sliogeris and Roads Corporation 1992), assessed the effects of an increased speed limit (from 100 kph to 110 kph) on rural and outer Melbourne freeway networks in 1987, which was later reduced in 1989. Results indicated an increase in injury crash rate (including fatalities) per kilometer traveled of 24.6 percent when the speed limit was raised in 1987, and a decrease of 19.3 percent when the limit was lowered in 1989. These results were in comparison to a control group. Finally, one more informative piece of evidence (Graham and Sparkes 2010), from New South Wales, Australia, indicated a 45 percent reduction in vehicle-and-pedestrian crashes, after implementation of an initiative to reduce speeds to 40 kph in school zones.

Road traffic operational environments in LMICs, however, are very different than in high-income countries (HICs), with a mix of vehicles and other road users sharing road space—fleets of cars along with bicycles, trucks, and other modes of transport, in addition to pedestrians. Controlling or managing vehicle speeds is a complex and challenging task because of factors such as inadequate enforcement, a different road safety culture, and/or lack of driver discipline.

While most of the studies mentioned earlier (except the Brazil study) were undertaken in the context of HICs, speed management follows the basic rule of physics and should be applicable everywhere. The literature reviews also did not find any such speed limit reduction programs in the Asian context. As a result, experience and lessons from an Asian country in this context will add immense value—not only to the existing state of knowledge, but also for speed management in World Bank client countries that have a similar or at least comparable context.

## Methods of Evaluation of Effectiveness

Because monitoring and evaluation of road safety interventions—or "treatments"—is as important as the selection of the interventions, to assess the effectiveness of a treatment researchers rely on three primary evaluation methods or approaches, each ranging in complexity: 1) cross-sectional studies 2) before-after studies, and 3) experimental before-after studies.

**Cross-sectional studies** compare safety performance of sites with a particular safety feature (or features) with sites that do not have the same feature. These studies assume the difference in safety performance is due to this feature (or lack thereof). Using the cross-sectional approach can be problematic, as it fails to control external factors, and does not adequately handle regression to the mean. Thus, the cross-sectional approach is not recommended for evaluation of treatments.

Before-after studies may or may not involve comparison sites. The most basic form of evaluation is to simply compare crashes in the period before an intervention is installed with the crashes after (termed as a simple before-after or naïve before-after study—that is, without a comparison group). This approach is also not recommended, as it does not adequately account for regression to the mean or external variables.

**Before-after studies with comparison groups**, is the most commonly applied method for the evaluation of infrastructure treatment. ,  comparison groups. Even though this approach does not fully address the issue of regression to the mean (however, using a longer "before" time period can reduce this effect), it does limit the impact of external factors. The approach compares the outcomes at the treatment group with the outcomes at a set of comparison group (sometimes termed "control" sites), which have similar characteristics to the treatment sites in all important aspects, except that the treatment is not installed. This approach assumes external factors act on both the treatment sites and the comparison sites in an identical way, and so each can be allowed for and measured. Since the treatment sites and the comparison sites are subject to the same sets of external variables, any difference in safety outcomes must be due to the treatment.

In road safety literature, however, the most recommended approach for evaluation of infrastructure interventions is the Empirical Bayes (or EB) method as explained by Hauer (1997). This method has been designed to account for regression to the mean and other factors that could affect crash outcomes without random allocation of the sites to treatment and nontreatment conditions. The procedure is based on the premise that what would have happened without a treatment can be estimated by extrapolating what happened at the trial sites in the past, adjusted to make allowance as far as possible for extraneous factors such as traffic flow, among others, and more general changes affecting the entire road network (for example, weather, compliance with road rules, or changes to vehicles). Safety performance functions are also developed to estimate the expected number of crashes for a site. However, this method requires more data, which is often a **practical challenge**.

**Experimental before-after studies** offer the most control, and allow investigators an active role in influencing the selection of sites for treatment. This method usually takes the form of randomly allocating sites to the treatment group or the control group, the "gold standard" in evaluation methodology. However, such an approach is very rare in evaluation of infrastructure interventions, as many external elements are beyond the control of the investigator in most observational studies, not to mention the ethical aspect that high risk sites cannot be left untreated.[1]

1 For more details on evaluation methods, please refer to the Association of Australian and New Zealand Road Transport and Traffic Authorities (Austroads) report, *An Introductory Guide for Evaluating Effectiveness of Road Safety Treatments* (Cairney, Turner, and Steinmetz 2012).

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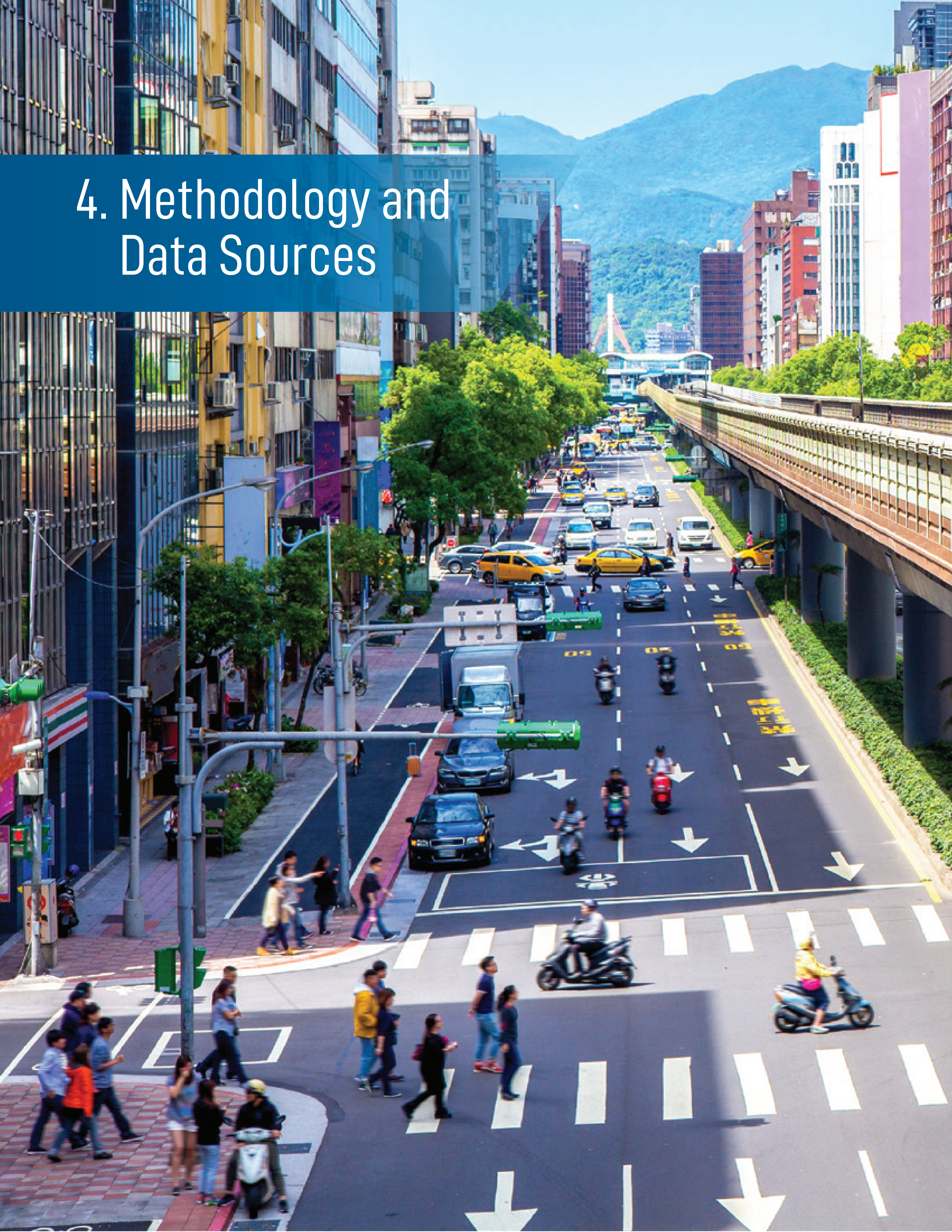
# 4. Methodology and Data Sources



To evaluate the effectiveness of the treatment—"speed limit reductions"—the study team used an observational before-after study with a control group. Following the method by Hauer (1997) , as described below, the team obtained counts of crashes before and after in both treatment site and comparison group, comparing the totals to quantify the benefit of the treatment, if any. The team conducted several different analyses to check the impact of speed limit reductions on the following: 1) the total number of crashes, 2) vehicle-to-vehicle crashes, and 3) vehicle-to-pedestrian crashes.

In an observation before-after study involving a treatment and a comparison group, let K and L denote the corresponding before and after crash counts in the treatment groups, and M and N are the before and after crash counts in the comparison group. The expected values of these crash counts are denoted by the corresponding Greek letters $\kappa, \lambda, \mu,$ and $\nu$ respectively.

The Comparison Group (C-G) method is based on the hope that in the absence of treatment, the ratio of the expected number of target crashes "before" and "after" would be the same in the treatment and comparisons groups. To bring the hope into the orbit of explicit analysis, Hauer (1997) distinguished between the ratio $r_C$ defined for the comparison group and a parallel but distinct ratio for the treatment group.

Thus, defined as:

$r_C \doteq \nu / \mu$ to be the ratio of the expected crash counts for the comparison group, and

$r_T \doteq \pi / \kappa$ to be the corresponding ratio for the treatment group

(1)

Where,

$\pi =$ What the expected number of target crashes would have been in an "after" period without a treatment and

$\lambda =$ The expected number of target crashes in the "after" period at the treated sites

$\mu =$ The expected number of target crashes in the "before" period at comparison sites

$\nu =$ The expected number of target crashes in the "after" period at comparison sites

The aforementioned hope the following equation can be expressed:

$r_T = r_C$ or equivalent, that $r_C = r_T = 1$

(2)

From the definition of rT it follows that

$$\pi = r_T \kappa$$

(3)

Therefore, if the assumption in Equation (2) is true, then it is also true that

$$\pi = r_C \kappa$$

(4)

Since $r_C$ in equation 4 can be estimated from the number of crashes in the comparison group ($M$ and $N$), and κ can be estimated by the number of crashes in the treatment group in the "before" period ($K$), $\pi$ can be estimated. While equation $2$ is an assumption, the only defensible argument put forward by the author was to justify the use of a comparison group in an observational study is empirical or inductive. Also, if one can show that in a time series of past values $r_T$ and $r_C$ were sufficiently similar then, cognizant of the usual limitations of all inductive arguments, one might hope the past similarity also held for that specific value of $r_C$ used in a specific C-G study. However, if this is the argument on which the C-G method rests, one must allow in the analysis for the possibility that the assumption $r_C / r_T = 1$ is not exactly true in any specific C-G study. It is therefore necessary to consider that ratio $r_C / r_T$ to be a random variable which on different occasions takes on different values. Consistent with the usual statistical terminology associated the ratio $r_C / r_T$ will be called the "odds ratio" and given the symbol $\omega$.

$$\omega \doteq r_C / r_T \quad (5)$$

However, for the purpose of C-G study, Hauer (1997) suggested the following steps:

Step 1: Estimates of parameters:

$$\hat{\lambda} = L,\ \hat{r_T} = \hat{r_C}\ (N/M)/(1+1/M) \simeq N/M,\ \hat{\pi} = \hat{r_T} K$$

Step 2:

$$\hat{VAR}\{\lambda\} = L, \hat{VAR}\{\hat{r_T}\}) / r_T^2 = 1/M + 1/N + \hat{VAR}\{\omega\},$$
$$\hat{VAR}\{\hat{\pi}\} \simeq \hat{\pi}^2\ [1/K + \hat{VA R}\{\hat{r_T}\}/r_T^2]$$

Step 3:

$$\hat{\delta} = \pi - \lambda,\ VAR\{\hat{\delta}\} = VAR\{\hat{\pi}\} + VAR\{\hat{\lambda}\}$$

Step 4:

$$\theta^* = (\lambda/\pi)/[1 + VAR\{\hat{\pi}\}/\pi^2],\ VAR\{\hat{\theta}\} \simeq \theta^2\ [(VAR\{\hat{\lambda}\}/\lambda^2) + (VAR\{\hat{\pi}\}/\pi^2)] / [1 + VAR\{\hat{\pi}\}/\pi^2]^2$$

In the simple before-after method $\hat{\pi} = K$, whereas in the C-G method, $\hat{\pi} = \hat{r_T} K$. The purpose of $\hat{r_T}$ (or of its replacement $\hat{r_C}$) is to count for the effect of change in various uncontrolled causal factors.

To assess the impact of speed limit reductions on safety performance, the study team used crash data from Daegu Metropolitan City (hereinafter Daegu) from between the years 2013 and 2018. The Korea Transport Institute (KOTI) selected the entire target analysis period, looking at the three years before (2013~2015) and the three years after (2016~2018), during which time Daegu actively pursued speed limit changes at all treatment sites.

For the comparison groups, that is the sites where speed limits remained unchanged, a similar duration of three years before (2013~2015) and three years after (2016~2018) was chosen. While the road geometry and traffic volumes in treatment and comparison groups are not identical, they are comparable as reported by KOTI. However, it is important to keep in mind treated sections generally experience higher rates of crashes, fatalities, and injuries than untreated sections. In addition, bias is likely in before-the-change crashes in the treated sections, as randomly allocating sites to the treatment group or the control group is often difficult.

As mentioned earlier, the Korean National Police Agency adopted the speed management initiative known as "Safety Speed 5030" in 2016, and in several urban areas, the arterial speed limits are set at 50 kilometers per hour (kph), with side-road speeds set at 30 kph (or sometimes 20 kph) for better road safety, as the photos show in figures 4.1 and 4.2. However, as reported by KOTI, not much has changed in road infrastructure; to date, only speed limit signs and road markings have been updated. **As a result, safety assessment in this study primarily captures the effects of speed limit change, without associated traffic calming measures.**

For the selection of target roads, the KOTI team investigated major cities actively implementing speed limit reductions as candidate regions in terms of the current state of speed limit changes. Seoul, Daegu, Daejeon, Chungbuk, Jeonnam, Kyeongbuk, Jeju, and seven other local police agencies announced speed limit changes on their respective homepages. Table 4.1 shows the results from a survey of the speed limit reduction sections.

**Figure 4.1.** 30 kph Limit in Residential and Commercial Neighborhoods (with Pavement Marking)


**a. Residential neighborhood**

**b. Commercial neighborhood**

**Source:** Original images captured for this publication.

**Figure 4.2.** Pedestrian Priority Zone with 20 kph Limit and Modified Pavement Texture


**Source:** Original images captured for this publication.

As shown in table 4.1, Seoul implemented reduced speed limits at a total of 2,534 locations, mostly in protected areas such as school zones; Daegu implemented limits in 865 locations; Deajeon implemented in 168 locations, and so on.

Of the candidate regions, Daegu was chosen as the target region because of its high number of speed limit reduction sections and diverse speed limit cases. Daegu has reduced the speed limits in 865 location across 54 roads, excluding those of protection zones, from 40~80 kph to 30~70 kph. Table 4.2 shows all such modified cases with the original speed limit, the lowered speed, limit, and the numbers of roads where speed reductions have been implemented.

**Table 4.1.** Current Status of Lowering Speed Limits across Korea

| Local government | Number of reduction sections | Official data release date | Other |
|---|---:|---:|---|
| Seoul City | 2,534 | 08/31/2016 | Speed limit reductions tend to be 30 kph reduction sections due to designation as protection zones |
| Daegu City | 865 | 09/2017 | — |
| Daejeon City | 168 | 08/22/2016 | — |
| Chungcheongbuk-do Province | 253 | 08/30/2011 | — |
| Jeollanam-do Province | 754 | 09/19/2016 | — |
| Gyeongsangbuk-do Province | 313 | 08/31/2016 | — |
| Jeju-do Province | 162 | 04/2019 | — |

**Source:** Original calculations produced for this publication.

**Table 4.2.** The Current Status of Lowering Speed Limits in Daegu Metropolitan City

<table>
<tr><th>Case</th><th>Current speed limit (kph)</th><th>Modified speed limit (kph)</th><th>Number of roads</th><th>Number of control roads</th></tr>
<tr><td>1</td><td>80</td><td>70</td><td>2</td><td>1</td></tr>
<tr><td>2</td><td>70</td><td>60</td><td>19</td><td>3</td></tr>
<tr><td>3</td><td>60</td><td>50</td><td>18</td><td rowspan="3">30</td></tr>
<tr><td>4</td><td>60</td><td>40</td><td>3</td></tr>
<tr><td>5</td><td>60</td><td>30</td><td>3</td></tr>
<tr><td>6</td><td>50</td><td>40</td><td>1</td><td rowspan="2">29</td></tr>
<tr><td>7</td><td>50</td><td>30</td><td>5</td></tr>
<tr><td>8</td><td>40</td><td>30</td><td>3</td><td>11</td></tr>
</table>

**Source:** Original calculations produced for this publication.

Finally, to compare the impact of a speed limit reduction—as well as signal delay—on travel time, the study team selected three different road sections in Ulsan Metropolitan City and measured individual vehicle speeds to assess the effects of a speed limit change on overall travel time. While the ideal data for such comparison would have been travel time collected at the before-and-after period from the same road sections, such data were not available, hence influences on speed could only be estimated from three similar road sections with different speed limits.

The three Ulsan road sections include the following: (1) the 2.3 kilometer extension section on Hwahop-ro (with a speed limit of 50 kph); (2) the 2.3 kilometer extension section on Samsan-ro (with a speed limit of 60 kph); and (3) the 2.3 kilometer extension section on Moonsu-ro (also with a speed limit of 60 kph). To enhance the accuracy of the assessment, peak and off-peak times were separated: 08:00~09:00 a.m. was selected as peak time, and 23:00~midnight as off-peak time.

## References

Hauer, Ezra. 1997. *Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety."* Oxford, United Kingdom: Pergamon, Elsevier Science, Ltd.

# 5. Results

# Assessment of Safety Benefit from Speed Limit Reductions

This section presents the results of safety assessment from reduced speed limits (mostly sign-only as very few infrastructure-based speed management measures have been implemented) in terms of reductions in crashes, fatalities, and injuries, if any. A reduction in vehicle and pedestrian crashes and injuries would be expected as a result of a reduction in average speed and top percentile speeds due to speed limit reductions as well as an increase in driver awareness and alertness about speed limit reductions. However, if speed limit reductions do not result in actual reductions in the average speed of operation, it might not be effective to simply reduce speed limits, without associated infrastructure and enforcement to support the new limits.

## Before vs. after comparison of total crashes

To begin, the study team compared total crash counts for Daegu for the three years before the change (that is, 2013~2015) with those of the three years after the change (2016~2018) for the roads where speed limits have been reduced. These sections are referred to here as "treatment groups." The "comparison groups" are roads of similar types where speed limits remained unchanged. For the comparison groups, the study team chose the same duration of before (2013~2015) and the same three years after (2016~2018).

**Table 5.1.** Before vs. After Comparison of Total Crashes

| | Number of crashes | Number of fatalities | Number of injuries | Equivalent property damage only crashes (EPDO) | Fatalities per 100 crashes |
|---|---|---|---|---|---|
| Before change in speed limit | 8,891 | 114 | 3,142 | 19,869 | 1.28 |
| After change in speed limit | 8,794 | 92 | 2,852 | 18,906 | 1.05 |
| **Percent reduction** | **1.1%** | **19.3%** | **9.2%** | **4.8%** | **18.4%** |
| Sections with unchanged speed limit, percent reduction | –3.0% | 6.8% | 11.8% | 3.0% | 9.6% |

**Source:** Original calculations produced for this publication.
**Note:** A negative (–) sign before the percent change indicates an increase; a positive (+) sign indicates a reduction.

A comparison of total crash counts, fatalities, and injuries, as conducted by the Korea Transport Institute (KOTI) is shown in table 5.1. This indicates reduced speed limits resulted in a consistent decrease in crash statistics across the board: a 1.1 percent decrease in total number of crashes, a 19.3 percent decrease in number of fatalities, and a 9.2 percent decrease in number of injuries in treatment groups, compared to reductions of 3 percent, 6.8 percent, and 11.8 percent respectively, in the comparison groups. Note that a negative (–) sign before the percent change indicates an increase; a positive (+) sign indicates a reduction. When compared with equivalent property damage only (EPDO) crashes and fatalities per 100 crashes, in both cases the reductions were higher at treatment sites compared to the control sites (similar road types in Daegu). The KOTI also reported results from chi-square tests to check if the reductions were statistically significant; however, the results are not promising due to a small sample, with the total number of crashes showing reductions only at a 14 percent level of significance.

However, when checked for effective reductions in crashes using the before-after method with comparison groups evidence point to reductions for both total crashes as well as fatalities. The reductions are estimated following the before-after methodology as stated in chapter 4 (Methodology and Data Sources), with results shown in table 5.2. The shaded columns with light blue colors correspond to results from the analysis of total crashes irrespective of road users and types. The results indicate a 4.2 percent reduction in total crashes, with a standard deviation of 4 percent, and a 15.2 percent reduction in fatalities with a standard deviation of 28 percent in the treatment groups, that is, at the sites with reduced speed limits.

**Table 5.2.** Calculation Table for Comparison of Crashes Using the Before-After Method with Control Groups

| Parameters | Crash | | | Fatalities | | | Serious Injuries | | |
|---|---|---|---|---|---|---|---|---|---|
| | All crashes | Vehicle-to-vehicle | Pedestrian | All crashes | Vehicle-to-vehicle | Pedestrian | All crashes | Vehicle-to-vehicle | Pedestrian |
| STEP 1 Find $\hat{\lambda}$ and $\hat{\pi}$ | | | | | | | | | |
| K | 8,891 | 7,194 | 1,407 | 114 | 42 | 62 | 3,142 | 2,321 | 677 |
| L | 8,794 | 7,049 | 1,477 | 92 | 41 | 38 | 2,852 | 2,045 | 693 |
| M | 3,467 | 2,568 | 820 | 44 | 11 | 27 | 1,305 | 876 | 395 |
| N | 3,575 | 2,720 | 801 | 38 | 12 | 20 | 1,159 | 772 | 369 |
| $\hat{\lambda} = L$ | 8,794 | 7,049 | 1,477 | 92 | 41 | 38 | 2,852 | 2,045 | 693 |
| Biased $\hat{r}_C$ | 1.03 | 1.06 | 0.98 | 0.86 | 1.09 | 0.74 | 0.89 | 0.88 | 0.93 |
| Unbiased $\hat{r}_T = \hat{r}_C (N/M)/(1+1/M) \simeq N/M$ | 1.03 | 1.06 | 0.98 | 0.84 | 1.00 | 0.71 | 0.89 | 0.88 | 0.93 |
| $\hat{\pi} = \hat{r}_T K$ | 9,165 | 7,617 | 1,373 | 96 | 42 | 44 | 2,788 | 2,043 | 631 |
| STEP 2 Find $V\hat{A}R\{\hat{\lambda}\}$ and $VAR\{\hat{\pi}\}$ | | | | | | | | | |
| $V\hat{A}R\{\hat{\lambda}\} = L$ | 8,794 | 7,049 | 1,477 | 92 | 41 | 38 | 2,852 | 2,045 | 693 |
| $\acute{\omega} = r_C / r_T$ | 1.000 | 1.000 | 1.001 | 1.023 | 1.091 | 1.037 | 1.001 | 1.001 | 1.003 |
| $V\hat{A}R\{\omega\}$ Approximation $\simeq 1/K + 1/L + 1/M + 1/N$ | 0.0008 | 0.0010 | 0.0039 | 0.0687 | 0.2224 | 0.1295 | 0.0023 | 0.0034 | 0.0082 |
| $V\hat{A}R\{\hat{r}_T\}/r_T^2 = 1/M + 1/N + V\hat{A}R\{\omega\}$ | 0.0014 | 0.0018 | 0.0063 | 0.1177 | 0.3967 | 0.2165 | 0.0039 | 0.0058 | 0.0134 |
| $V\hat{A}R\{\hat{\pi}\} \simeq \hat{\pi}^2 [1/K + V\hat{A}R\{\hat{r}_T\}/r_T^2]$ | 123,902 | 112,203 | 13,255 | 1,172 | 742 | 456 | 33,007 | 25,983 | 5,922 |

| Parameters | Crash | | | Fatalities | | | Serious Injuries | | |
|---|---|---|---|---|---|---|---|---|---|
| | All crashes | Vehicle-to-vehicle | Pedestrian | All crashes | Vehicle-to-vehicle | Pedestrian | All crashes | Vehicle-to-vehicle | Pedestrian |
| STEP 3 Find $\hat{\delta}$ and $\hat{\theta}$ | | | | | | | | | |
| $V\hat{A}R\{\hat{\pi}\}/\pi^2$ | 0.001 | 0.002 | 0.007 | 0.126 | 0.420 | 0.233 | 0.004 | 0.006 | 0.015 |
| $\hat{\delta}=\pi-\lambda$ | 371 | 568 | –104 | 4 | 1 | 6 | –64 | –2 | –62 |
| $\theta^{*}=(\lambda/\pi)/[1+VAR\{\hat{\pi}\}/\pi^2]$ | 0.958 | 0.924 | 1.068 | 0.848 | 0.687 | 0.696 | 1.019 | 0.995 | 1.082 |
| STEP 4 Find the estimate of $VAR\{\hat{\delta}\}$ and $VAR\{\hat{\theta}\}$ | | | | | | | | | |
| $\hat{\sigma}\{\hat{\delta}\}$ | 364 | 345 | 121 | 36 | 28 | 22 | 189 | 167 | 81 |
| $\hat{\sigma}\{\hat{\theta}\}$ | 0.04 | 0.04 | 0.09 | 0.28 | 0.32 | 0.29 | 0.07 | 0.08 | 0.14 |
| **Results** | | | | | | | | | |
| Reduction | 371 | 568 | –104 | 4 | 1 | 6 | –64 | –2 | –62 |
| Standard deviation | 364 | 345 | 121 | 36 | 28 | 22 | 189 | 167 | 81 |
| Amounts to a **x%** reduction | 4.2% | 7.6% | –6.8% | 15.2% | 31.3% | 30.4% | –1.9% | 0.5% | –8.2% |
| With a standard deviation of | 4% | 4% | 9% | 28% | 32% | 29% | 7% | 8% | 14% |

**Source:** Original calculations produced for this publication.

## Before vs. after comparison of vehicle-to-vehicle crashes

Following the same method, though using only vehicle-to-vehicle crashes for Daegu, the study compares crash records from three years before (2013~2015) and three years after (2016~2018), along with data for the same duration for the comparison groups. Results in table 5.3 show a decrease in crashes by 2.0 percent, in the number of fatalities by 2.4 percent, and in the number of injuries by 11.9 percent when comparing absolute numbers. However, when compared with the control sites, the study team observed both the number of crashes and the number of fatalities had increased at the control sites, but with no decrease in the number of crashes resulting in injuries.

**Table 5.3.** Before vs. After Comparison of Vehicle-to-Vehicle Crashes

| Total crashes (Vehicle-to vehicle) | Number of crashes | Number of fatalities | Number of injuries | Equivalent property damage only crashes (EPDO) | Fatalities per 100 crashes |
|---|---|---|---|---|---|
| Before change in speed limit | 7,194 | 42 | 2,321 | 15,737 | 0.58 |
| After change in speed limit | 7,049 | 41 | 2,045 | 15,002 | 0.58 |
| **Percent reduction** | **2.0%** | **2.4%** | **11.9%** | **4.7%** | **0.4%** |
| Sections with unchanged speed limit, percent reduction | –5.9% | –9.1% | 11.9% | 0.1% | –3.0% |

**Source:** Original calculations produced for this publication.
**Note:** A negative (–) sign before the percent change indicates an increase; a positive (+) sign indicates a reduction.

When checking results from table 5.2 for estimated actual reductions in the vehicle to vehicle crashes, fatalities, and injuries—keeping the crash trend at the control groups in mind—clear evidence emerges of a reduction in the total number of the vehicle to vehicle crashes. KOTI estimates using chi-square values also indicate statistically significant reductions of total vehicle-vehicle crashes at a 5 percent level of significance. The results from before-after using the comparison group for these crash types are presented in columns with light orange colors and the estimates show a 7.6 percent reduction in vehicle-vehicle crashes with a standard deviation of 4 percent. There is also evidence of reductions in fatalities, with a 31.3 percent reduction in numbers while controlling for reductions in the comparison group and with an estimated 32 percent standard deviation of the reduction.

## Before vs. after comparison of vehicle-to-pedestrian crashes

Vehicle-to-pedestrian crashes for Daegu from the three-year "before period" (2013~2015) are compared with crashes during the three-year "after period" (2016~2018) for the treatment groups. Similar to other crash types, the analysis period for the unchanged speed limit sections, that is, for the "control groups" consisting of similar road types, were also the same, with three years before (2013~2015) and the same three years after (2016~2018). A comparison of the total crash counts, fatalities, and injuries shows the reduction in speed limit resulted in a significant reduction in fatalities, though slightly increased the total number of crashes and injuries under this crash type.

As reported by KOTI and shown in table 5.4, the speed limit reductions resulted in an increased pedestrian crashes by 5.0 percent, and injury crashes by 2.4 percent, while fatalities decreased by 38.7 percent when an absolute number of vehicle-pedestrian crashes are considered in treatment groups, without considering the information from the comparison groups. Additionally, the EPDO coefficient reduced by 4.8 percent. Notably, in the control group, results show a decrease in crashes of all the categories, but at 5 percent level of significance, none of the differences is statistically significant.

**Table 5.4.** Before vs. After Comparison of Vehicle-to-Pedestrian Crashes

| Total crashes (Vehicle-pedestrian) | Number of crashes | Number of fatalities | Number of injuries | Equivalent property damage only crashes (EPDO) | Fatalities per 100 crashes |
|---|---|---|---|---|---|
| Before change in speed limit | 1,407 | 62 | 677 | 3,447 | 4.41 |
| After change in speed limit | 1,477 | 38 | 693 | 3,280 | 2.57 |
| **Percent reduction** | **–5.0%** | **38.7%** | **–2.4%** | **4.8%** | **41.6%** |
| Sections with unchanged speed limit, percent reduction | 2.3% | 25.9% | 6.6% | 8.8% | 24.2% |

**Source:** Original calculations produced for this publication.
**Note:** A negative (–) sign before the percent change indicates an increase; a positive (+) sign indicates a reduction.

Finally, when checked for effective reductions in pedestrian crashes due to speed limit reductions using the before-after method with comparison groups, evidence shows pedestrian fatalities decreased in the treatment groups compared to the decrease in pedestrian crashes in the control groups. The results indicate the reduced speed limits saved the lives of six pedestrians, which translates to a 30.4 percent reduction with a standard deviation of 29 percent as shared previously in table 5.2 (light green color). However, results show no reductions in total pedestrian crashes and injuries.

While the results from the overall safety assessment indicate some benefits from speed limit reductions, in the absence of detailed data on operating speed before and after, the compliance rate of such speed limit reductions cannot be confirmed. Further, reductions in crashes do not follow expectations, even when the overall decreasing trend of crashes, fatalities, and injuries in Daegu are taken into account with the help of "comparison groups."

# Assessment on Impact of Travel Time from Speed Limit Reductions

Table 5.5 shares results from the analysis of travel time due to two different speed limits as reported by KOTI. For the Hwahop-ro section with 50 kph speed limits, the nighttime average travel time was 285.0 seconds, while the morning peak travel time was 369.4 seconds. For Samsan-ro, nighttime average travel time was 249.3 seconds, while morning peak travel time was 313.5 seconds. For Moonsu-ro, nighttime average travel time was reported to be 289.8 seconds, while morning peak travel time was 643.0 seconds.

**Table 5.5.** A Comparison of Travel Time across Study Sections in Daegu Metropolitan City

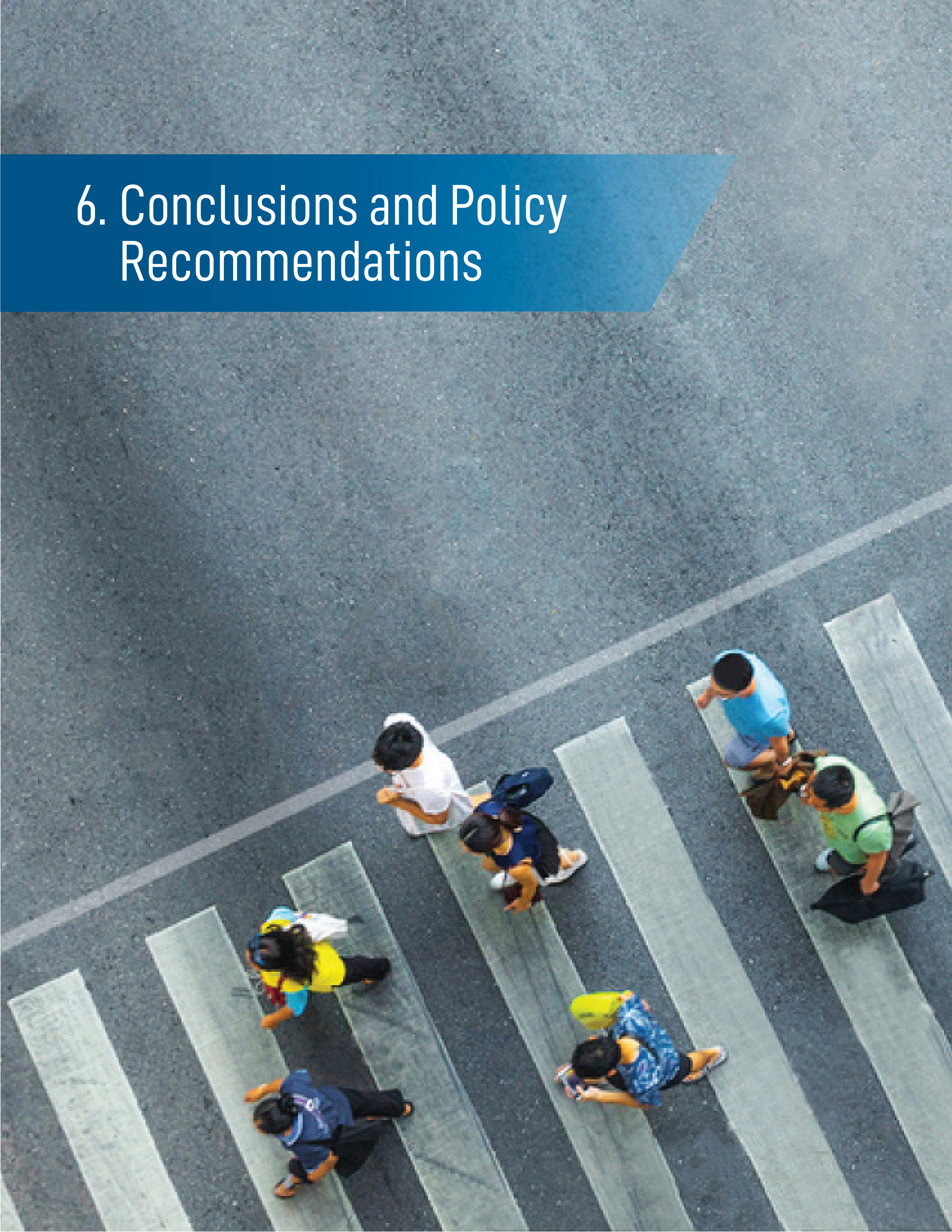
| Type | | Hwahop-ro | Samsan-ro | Moonsu-ro |
|---|---|---|---|---|
| Speed limit | | Speed 50 kph | Speed 60 kph | Speed 60 kph |
| Section extension | | 2.3km | 2.3km | 2.3km |
| Number of lanes | | 2 lanes | 4 lanes | 3 lanes |
| Free flow time (seconds) | | 166 sec | 138 sec | 138 sec |
| Travel time | Nighttime | 285.0 sec | 249.3 sec | 289.8 sec |
| | Morning peak | 369.4 sec | 313.5 sec | 634.0 sec |
| Intersection delay time | Nighttime | 119.0 sec (41.7%) | 111.3 sec (44.6%) | 151.8 sec (52.4%) |
| | Morning peak | 203.4 sec (55.1%) | 175.5 sec (56.0%) | 496.0 sec (78.2%) |
| Average number of intersection delays per vehicle | Nighttime | 1.0 times | 0.6 times | 1.9 times |
| | Morning peak | 1.7 times | 1.3 times | 3.8 times |
| Average travel speed for one-way road | Nighttime | Speed 46.0 kph | Speed 60.1 kph | Speed 56.7 kph |
| | Morning peak | Speed 43.3 kph | Speed 49.8 kph | Speed 34.1 kph |

**Source:** Original calculations produced for this publication.

Of the total travel times, the Hwahop-ro section shows the lowest proportion of delay time for both the nighttime and the morning peak. In turn, this indicates the efficiency of mobility is highest in the Hwahop-ro section, despite the lower speed limit of that road compared to the two other test sections.

While these promising results clearly indicate a higher speed limit does not necessarily translate into quicker travel time, collecting travel times before and after the change of posted speed limits from a particular corridor would also have been beneficial, as travel times are key performance indicators, and stand as a major hurdle to overcome while advocating for reduced speed limits. However, the study results clearly show a higher speed limit could very well result in greater delays and longer travel times.

# 6. Conclusions and Policy Recommendations



Speed is undeniably a key risk factor for road crash-related injuries and fatalities. Therefore, ensuring operational speeds are safe for all road users demands careful speed management driven by accurate data and supported by a process that yields success in other transportation environments. A first step in effective speed management is to discourage speeding through the use of appropriate speed limits.

However, garnering support from policy makers—and even transport professionals—for reducing speed limits is often an uphill battle for several reasons. First, neither group is fully convinced about the cause-and-effect of speeding and injuries and fatalities, and thus the immediate safety and health cost benefits of reducing speed. Second, they demonstrate an unwillingness to believe the research data indicating lower speed limits can actually improve traffic mobility, rather than creating longer travel times.

Third, many share a common misperception that the public pushes to drive at ever higher speeds—which is a myth. In reality, an authoritative survey, the E-Survey of Road Users' Attitudes (ESRA), conducted by the Brussels-based Vias institute, indicates fewer than 20 percent of road users find it acceptable to drive faster than the speed limit; fewer than 10 percent indicate that it is acceptable to speed in built-up areas; and most (up to 80 percent) believe speed is a cause of road crashes. Additionally, 90 percent of respondents suggest traffic rules should be stricter.[1]

As motorization, road development, and travel speeds continue to increase in low- to middle-income countries (LMICs), so do the road crashes, fatalities, and injuries. However, road development in LMICs can benefit from lessons learned in other countries, especially the lesson of safer mobility by managing speed on newly developed and/or upgraded roads. Korea's experience from speed limit reductions, which has likely resulted in reduced average speeds, along with additional benefits to road safety, could be very similar to those observed in other studies in the United Kingdom, Europe, and Australia. However, an evaluation conducted in Asia and collaboration with the World Bank could be more acceptable to neighboring Asian countries and developing countries in other regions.

Case in point: When the Korean National Police Agency initiated "Safety Speed 5030"—setting urban arterial speed limits at 50 kilometers per hour (kph) and side-road speed limits at 30 kph (and in some areas 20 kph)—ordinary Korean citizens did not organize major protests or voice mass disapproval against the initiative. However, the national police agency did launch a widespread campaign to win the hearts and minds of the Korean public and help sensitize them to the multiple and wide-ranging benefits of the speed limit reduction initiative. "You can see people, once you reduce speed" was the slogan widely promoted by means of video clips, posters, and other public relations materials, and the results of an experiment in Busan was circulated as a press release. The experiment demonstrated the total savings in travel time was only 2 minutes when two travelers maintained 50 kph and 60 kph while driving the identical routes of 15 kilometers long. Once the Korean public understood the issue, the speed limit reduction initiative received support.

1 To learn more about the E-Survey of Road Users' Attitudes (ESRA) coordinated by the Vias Institute in Brussels, Belgium, visit the ESRA website: https://www.esranet.eu.

Findings from the case study conducted in Daegu show a significant reduction in total and vehicle-to-vehicle crashes in the treated sites, and an overall reduction in fatalities, with six lives saved from vehicle-pedestrian crashes due to the treatment over the three-year period. However, this study is also not without limitations: First, no robust data collection was done before and after speed limit reductions to check speed compliance and the actual reductions in average speeds. As a result, the effect of speed limit reductions on average operating speed is largely unknown for this study. Further, research evidence shows different speed limit reductions will result in different reductions in average speeds. As a result, it would have been more scientific to conduct separate safety assessments for roads with different speed limit reductions. However, this was not possible due to the small sample sizes with lower-level confidence, which needs to be studied further to determine the long-term impact of the speed limit reductions. Regardless of the study's shortcomings, the results from the travel time analysis prove particularly promising, indicating a higher speed limit could very well result in greater delays and longer travel times. The practical implication of this is that concerns about longer travel times are misplaced and should not prevent transportation planners and regulators from lowering speed limits to enhance road safety.

Based on the earlier studies, and from this research, the study team concludes that in general, speed limit reductions—supported by strong visuals and engineering treatments—go further in generating substantial compliance and subsequently, the safety benefits. However, such engineering treatments to implement active measures of speed control have been limited in this current study. While the impact of speed limits combined with supporting engineering treatments on road safety is significant, the study did not have enough sample to analyze these effects in Korea. It is, therefore, strongly recommended to prioritize installing traffic calming measures on the road with a speed limit less than or equal to 30 kph. Even with these limitations, this KOTI-World Bank joint study begins to fill that gap with far-reaching implications with the potential to initiate policy dialogue on speed limit reductions in developing countries in Asia and elsewhere.

**Lessons for World Bank operations:** With increased emphasis on road safety in World Bank operations, speed management and providing engineering measures to support context-sensitive operating speed has become increasingly important. Task team leaders (TTLs) also need to appreciate the safety benefits of appropriate speed limits and other associated measures to increase speed compliance resulting in better safety outcomes for their projects. It is thus very important for TTLs to adopt good design practices, along with measures of performance, to achieve the desired level of safety outcomes with intermediate outcome indicators for their projects. For this purpose, gathering all relevant base data is essential as part of the project preparation, to support a rich and useful result framework. From that point of view, the experience of KOTI-WB collaboration will guide Word Bank TTLs to help achieve the desired project results.