# 12. Traffic safety pillars: safe speeds

## Introduction

Speed is fundamental for traffic safety since, ultimately, it is the kinetic energy released during a collision that causes damage, personal injuries, and fatalities. Managing the kinetic energy—the main 'pathogen' in traffic safety—is at the core of building the Safe System. A 'safe' speed limit for any given type of traffic environment is derived from consideration of possible accident scenarios and ensuring that the released kinetic energy will not exceed the biomechanical tolerance of the human body. 'Safe speeds' are most effectively secured by infrastructure and in-vehicle measures, and less so by road user education and enforcement.

## Learning outcomes

After completing this module, the students should be able to:

- explain in kinematic terms how speed affects the level of kinetic energy, stopping distance, collision speed, and ability to avoid a collision
- know basic relations between accident risks and speeds of individual vehicles and traffic flow in general
- know the basic relations between the collision speed and injury severity for different accident scenarios
- know the recommended 'safe speeds' for typical traffic environments
- explain the thinking process behind deciding on the 'safe speed' for a given traffic environment
- know the best practices in police and automated speed enforcement
- know the most common infrastructure and in-vehicle measure for speed compliance
- perform basic speed data collection, analysis, present and discuss the results
- apply Power Model to estimate changes in injury/fatal accident risks due to changes in flow speed

## Key messages to learners

- Nearly all aspects of speed are negatively related to traffic safety, both at individual and aggregated level. Higher initial speed increases the stopping distance, ability to avoid a collision, and the collision speed when it cannot be avoided. Increasing individual speed and driving faster than the flow increase accident risk for the driver. Increase of the average flow speed and speed variation between the vehicles increase accident frequency. Empirical relationships such as Power Model clearly illustrate how even small speed reductions can have a significant effect on injury and fatality risks.
- Any system of speed limits is a compromise between considerations pulling in opposite directions. Low speed limits are good for safety but increase travel time.
- Historically, speed limits were often decided based on: (*i*) road users' preferences, for example by setting the speed limit at 85%-percentile of all vehicle speeds on the road; (*ii*) economic optimizations, taking into account costs of accidents, travel time, vehicle operation, noise, air

pollution, etc. The first approach has very weak theoretical grounds, while the second has serious moral implications.

- According to the Vision Zero, it is not acceptable to justify existence of traffic fatalities and severe injuries by improved travel times or reduced pollution; thus, the goal of Safe System is to ensure acceptable quality of mobility, under condition that it does not result in serious personal injuries.
- Injury biomechanics studies the relations between the impact energy on a human body and injuries it produces. The energy released in a collision is primarily the kinetic energy of moving vehicles (i.e. a direct function of speed), and there is a solid bulk of knowledge available relating collision speed to the risk of severe injuries and fatalities for different types of accidents and road users involved.
- Safe System uses the concept of 'safe speed' for a given traffic environment. Its basic principle is that the highest speed level to be allowed is chosen so that in any conceivable accident scenario, people involved will not be exposed to energies exceeding their biomechanical tolerance (i.e. chances for severe/fatal injuries are very low).
- A simple rule of thumb for 'safe speed' is: (*i*) 30 km/h for environments where unprotected road users (pedestrians, cyclist, etc.) directly interact with motor vehicles; (*ii*) 50 km/h where right-angle collisions are possible (e.g. at intersections); (*iii*) 70/80 km/h where frontal collisions are possible (unseparated two-directional roads); (*iv*) higher speeds can only be allowed where vehicles moving in opposite directions are physically separated.
- Setting a 'safe' speed limit is usually not sufficient to reach the desired speed regime. Violations of speed limits is widespread in all countries. It is not uncommon for 30%–50% of vehicles to drive above speed limits. Such behaviour is often supported by social norms that associate 'good driving' with driving at high speeds, while breaking the speed limits not considered to be a serious offence.
- Police enforcement has its role for improving speed limit compliance, but realistically it can only be used for short time periods and limited geographical areas. Additionally, the existence of corruption may undermine the efforts. Therefore, technical solutions such as automated speed control, as well as infrastructure and in-vehicle measures are considered much more impactful.
- Automated speed enforcement is usually done with speed cameras that detect vehicles exceeding the speed limit and extract the necessary information for issuing a fine ticket from the image (vehicle registration number, etc.). Single camera controls often result in 'kangaroo-driving', i.e. the driver slowing down before the camera and then accelerating immediately to the original speed. This is addressed by section speed controls that use two cameras registering the travel time over a longer distance. Regardless of the technology used, it is important to remember that the purpose of such controls is to ensure a safe speed regime and not to collect more money from drivers. Better speed compliance is achieved by making the speed cameras visible and informing the drivers about speed controls well in advance.
- On the infrastructure side, traffic calming solutions (humps, road narrowing, chicanes, small roundabouts, etc.) have been shown very effective in urban settings. On rural roads, positive speed reduction effects are well-documented for conversion of intersections into roundabouts as well as for chicanes adjusted for higher speeds (usually built before intersections or at entrances into areas with lower speed limits—so called 'village gates').
- Modern vehicles can assist the driver in complying with the speed limits. The degree of assistance varies from merely informing about the current speed limit to a warning about exceeding it and ultimately to active interventions that force the vehicle to slow down. Intelligent speed assistance (ISA) technology has existed for more than 30 years but is still not

mandatory or widely used on a voluntary basis. It is estimated, however, that equipment of all vehicles with 'active' speed assistance (making them always compliant with speed limits), would have reduced traffic fatalities dramatically (by up to 25%).

## Learning activities

### Exercise 1

Preparations (teacher only):

- Generate four columns of speed data, ca 100 each. This will represent before and after (some safety measure introduction) measurements at two locations. Think of a possible speed limit and make sure that some speeds exceed it.

| | Before 1 | Before 2 | After 1 | After 2 |
|---|---|---|---|---|
| 1 | 91,6 | 90,2 | 80,7 | 85,0 |
| 2 | 88,3 | 94,6 | 79,3 | 82,5 |
| 3 | 93,9 | 98,7 | 76,7 | 80,8 |
| 4 | 94,3 | 94,1 | 73,1 | 79,5 |
| 5 | 90,7 | 88,9 | 90,5 | 88,4 |
| 6 | 98,6 | 92,5 | 90,1 | 91,2 |
| 7 | 90,2 | 89,2 | 81,7 | 82,0 |
| 8 | 94,2 | 88,7 | 78,1 | 83,6 |
| 9 | 92,9 | 94,5 | 69,0 | 79,5 |
| 10 | 92,3 | 97,5 | 73,2 | 83,4 |
| 11 | 91,8 | 95,3 | 88,6 | 79,3 |
| 12 | 92,8 | 91,7 | 76,4 | 84,8 |
| 13 | 91,4 | 96,0 | 78,4 | 82,3 |
| 14 | 90,4 | 87,0 | 73,4 | 85,3 |
| 15 | 93,8 | 94,7 | 78,1 | 81,3 |
| ... | ... | ... | ... | ... |
| 100 | 92,6 | 91,7 | 85,2 | 85,8 |

With the students:

1. In Excel, create cumulative graphs showing speed distributions at both locations, before and after.
2. For each case, calculate the average speed, 85-percentile and share of drivers travelling faster than the speed limit.
3. Calculate confidence intervals for the average speed values. Perform a statistical test to find out whether the before/after change in the average speed (at each location) is statistically significant at 95%-level.
4. Reflect on the shapes of the cumulative curves in before/after situations. For example, have the curve moved left or right? Has it become more compact (less variation in speeds)? Has both the average and 85-percentile decreased/increased? How has the share of drivers who overspeed changed, increased or decreased?
5. Assume the accident risk before speed reduction was one fatal and three injury accidents in 10 years. Using Power Model, calculate the expected frequency of fatal and injury accidents after the speed reduction. What is the accident risk reduction in per cent for each accident type?

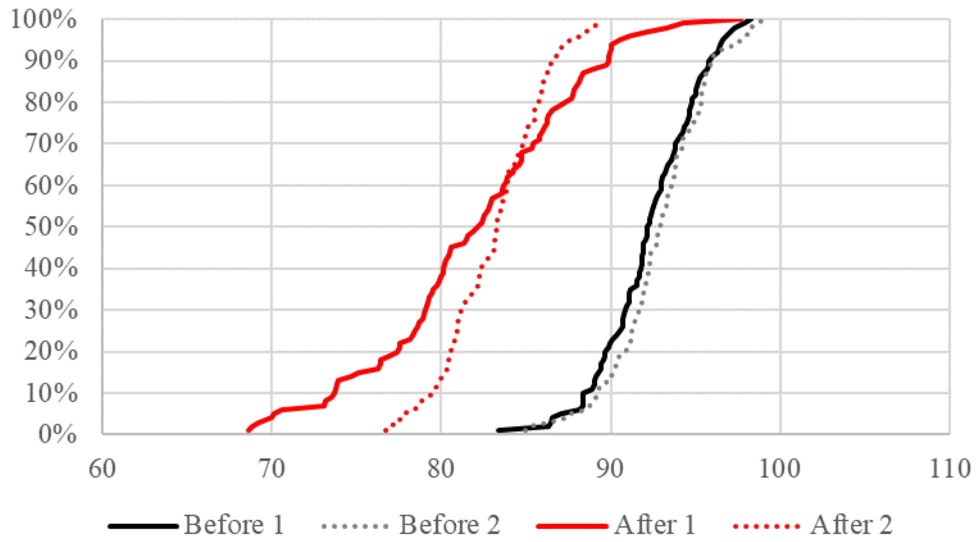
$$Fatal\ accidents_{after} = Fatal\ accidents_{before} \cdot \left(\frac{V_{after}}{V_{before}}\right)^4$$

$$Injury\ accidents_{after} = Injury\ accidents_{before} \cdot \left(\frac{V_{after}}{V_{before}}\right)^2$$

6. It is obvious that even though the speed limit has been changed, many cars continue to drive faster than the speed limit. Calculate how much time does a car driving with a speed 7 km/h above the speed limit of 80 km/h saves over a 50 km trip. Is it worth it?

**Possible answer:**

1. Cumulative curves. In this example, the speed limit was change at both locations from 90 km/h to 80 km/h.




2. Descriptive statistics:

| | Average speed, km/h | St. deviation, km/h | 85-percentile, km/h | % above speed limit |
|---|---|---|---|---|
| Before 1 | 92.3 | 2.8 | 95.2 | 78% |
| Before 2 | 92.9 | 2.8 | 95.5 | 87% |
| After 1 | 82.0 | 6.0 | 88.1 | 62% |
| After 2 | 83.1 | 2.9 | 86.1 | 87% |

3. Confidence intervals:

| | Average speed, km/h | St. deviation, km/h | 95 % CI lower | 95 % CI upper |
|---|---|---|---|---|
| Before 1 | 92.3 | 2.8 | 91.7 | 92.9 |
| Before 2 | 92.9 | 2.8 | 92.3 | 93.5 |
| After 1 | 82.0 | 6.0 | 80.8 | 83.2 |
| After 2 | 83.1 | 2.9 | 82.6 | 83.7 |

T.TEST() function in Excel calculate the *p*-values for the *t*-test. A simple visual clue is that if the confidence intervals for before and after periods overlap, the difference in average speeds will not be statistically significant.

4. Reflections on the curve shapes. At both sites, the speeds have reduced (curves moved to the left). However, at the site 1, the spreading of the speeds became larger. Therefore, while the average speed at site 1 became lower than at site 2, the 85-percentile is actually higher. Since in traffic safety the high speeds are of most importance, the situation at site 2 could be considered more beneficial for safety.

Note how large share of drivers have speeds above the speed limit, both before and after. This is a typical example of ‘speeding just a little’ not considered to be a serious offence. Some drivers, however, exceed the limit by nearly 20 km/h (site 1, after situation).

5. Power model calculations:

| | Average speed, | Accidents per year | | % reduction | |
|---|---|---|---|---|---|
| | km/h | Fatal | Injury | Fatal | Injury |
| Before 1 | 92.3 | 0.100 | 0.300 | - | - |
| Before 2 | 92.9 | 0.100 | 0.300 | - | - |
| After 1 | 82.0 | 0.062 | 0.237 | 38% | 21% |
| After 2 | 83.1 | 0.064 | 0.240 | 36% | 20% |

6. Driving 50 km at 80 km/h (speed limit) takes 50 / 80 = 37.5 minutes. When speeding by 7 km/h, the trip takes 50 / 87 = 34.5 minutes. Total time saving is 3 minutes (compared to 37.5 minutes of the trip duration, the win is quite negligible).

## Assessment quiz

The assessment quiz can be used as a part of the examination, or as another form of learning activities.

### Question 1

According to the Power Model, increasing the average speed on a road section by 10% will lead to increase of the fatal accident risk by:

- 10% (incorrect)
- 22% (incorrect)
- 46% (correct)
- 84% (incorrect)

**Comment** (shown after the answer has been given): $1.1^4 = 1.46$, i.e. 46% increase in fatal accidents.

### Question 2

The accident risk increases if you …

- ... drive faster than the speed limit. (correct)
- ... drive faster than the rest of the traffic around you. (correct)

- ... decrease your travelling speed in general, since you will spend more time exposed to traffic. (incorrect)
- ... drive slower than the rest of the traffic around you. (incorrect)
- ... increase your travelling speed in general. (correct)

**Comment** (shown after the answer has been given): None

## Question 3

A driver detects a pedestrian crossing the road and hits the brakes. The vehicle's speed will strongly affect...

- ... stopping distance (distance travelled from the moment the driver detects the pedestrian to the moment the vehicle comes to a complete stop) (correct)

  **Comment** (shown after the answer has been given): The higher is the initial speed, the longer the vehicle will travel before reaching a complete stop.

- ... driver's reaction time (incorrect)

  **Comment** (shown after the answer has been given): The reaction time itself is not really affected by the speed. However, the same reaction time of, say, 1 second will result in different distances travelled without the deceleration at different speeds. This will contribute to longer stopping distances at higher speeds.

- ... chances to avoid the collision (correct)

  **Comment** (shown after the answer has been given): Lower speeds result in shorter stopping distances; if the stopping distance is smaller than the distance to the pedestrian, collision will be avoided.

- ... collision speed (correct)

  **Comment** (shown after the answer has been given): If collision is unavoidable, the higher is the speed at the braking onset, the higher will be the speed at which the vehicle hits the pedestrian.

... severity of the pedestrian's injuries (correct)

  **Comment** (shown after the answer has been given): The higher is the collision speed, the higher energy is applied on the pedestrian's body, and the higher are the injury severity and probability of being killed.

- ... braking deceleration (incorrect)

  **Comment** (shown after the answer has been given): The deceleration strongly depends on the quality of the road surface (ice, water, leaves, sand, etc.), type of brakes (drum vs. disk), presence of ABS, etc. But everything else equal, the braking deceleration is relatively constant regardless of at which speed the braking was initiated.

## Question 4

According to the Safe System principles, ...

- ... you should not allow interactions between motor vehicles and vulnerable road users at speeds above 30 km/h. (correct)
- ... you should not use middle barriers on high-speed roads because you introduce a new type of accidents not present before—collisions between vehicles and the barrier. (incorrect)

**Comment** (shown after the answer has been given): While the collisions with middle barriers do occur, the severity of such accidents is minor compared to prevented head-on collisions at high speeds that frequently lead to severe injuries and fatalities.

- ... you should separate opposite traffic flows at speeds above 70 km/h (for modern cars, above 80 km/h). (correct)
- … you should clearly mark zebra crossings located at high-speed roads and motorways. (incorrect)

  **Comment** (shown after the answer has been given): According to the Safe System principles, you should not allow interaction of pedestrian with traffic at high speeds. Zebra crossings do not belong at high-speed roads.
- ... you should use right angle intersections only if the speed limit is 50 km/h or lower. (correct)
- ... you should not allow speeds above 110 km/h in the areas where large wild animals might turn up. (correct)

## Recommended reading and resources for students


- Cykelviden.dk. (2022). *Traffic calming in cities: handbook of solutions*. Danish Centre for Cycling Knowledge. https://api.vejdirektoratet.dk/sites/default/files/2023-05/Trafikal%20fredeligg%C3%B8relse%20i%20byer_ENGELSK_final.pdf
- GRSP. (2023). *Speed management: a road safety manual for decision-makers and practitioners*. Global Road Safety Partnership. https://www.grsproadsafety.org/wp-content/uploads/2023/10/Green-Manual-Speed-revised-edition-16Oct23.pdf
- Hall, C., Beer, K., Robertson, J., Nguyen, T., Zafar, F., Tan, T., Mani, A., & Beer, T. (2021). *Guide to Road Safety Part 3: Safe Speed* (AGRS03-21). Austroads. https://austroads.com.au/publications/road-safety/agrs03
- ITF. (2018). *Speed and crash risk*. International Transport Forum. https://www.itf-oecd.org/sites/default/files/docs/speed-crash-risk.pdf
- Yannis, G., & Michelaraki, E. (2024). Effectiveness of 30 km/h speed limit—a literature review. *Journal of Safety Research*, *92*, 490–503. https://doi.org/10.1016/j.jsr.2024.11.003


## Recommended (additional) reading for teacher


- Aarts, L., & van Schagen, I. (2006). Driving speed and the risk of road crashes: a review. *Accident Analysis & Prevention*, *38*, 215–224. https://doi.org/10.1016/j.aap.2005.07.004
- Doecke, S. D., Baldock, M. R. J., Kloeden, C. N., & Dutschke, J. K. (2020). Impact speed and the risk of serious injury in vehicle crashes. *Accident Analysis & Prevention*, 144, 105629. https://doi.org/10.1016/j.aap.2020.105629
- Elvik, R. (2019). A comprehensive and unified framework for analysing the effects on injuries of measures influencing speed. *Accident Analysis & Prevention*, 125, 63–69. https://doi.org/10.1016/j.aap.2019.01.033
- Elvik, R., Vadeby, A., Hels, T., & van Schagen, I. (2019). Updated estimates of the relationship between speed and road safety at the aggregate and individual levels. *Accident Analysis & Prevention*, 123, 114–122. https://doi.org/10.1016/j.aap.2018.11.014
- Hussain, Q., Feng, H., Grzebieta, R., Brijs, T., & Olivier, J. (2019). The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta-analysis. *Accident Analysis & Prevention*, 129, 241–249. https://doi.org/10.1016/j.aap.2019.05.033

- SWOV. (2003). *Traffic calming schemes* (R-2003-22). SWOV Institute for Road Safety Research. https://swov.nl/system/files/publication-downloads/r-2003-22.pdf

## Prepared by expert

In case you have specific questions, need a discussion partner, or just want feedback on your lecture materials, you may reach out the author(s) of this module. Please, put 'AfroSAFE curriculum' in the email subject.

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