

## Summary

# Safety effects of cross section elements

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*Safety relevant cross section elements include the median and the number of lanes, as well as the width of the pavement, lane, and shoulder. This report presents results from a review of international literature on these cross section elements, and an analysis of Norwegian rural to-lane roads. Road width: All else being equal (including traffic volume and the number of lanes), wider roads have on average fewer crashes than narrower roads, especially at high volumes. Most studies indicate that both wider lanes and wider shoulders are associated with fewer crashes than narrower lanes, especially at high volumes. However, at low volumes, some studies found increasing crash numbers at increasing lane widths. For a given road width, wider shoulders, rather than wider lanes, are found to be most beneficial for safety in most cases. Number of lanes: Most studies indicate that four-lane roads have fewer crashes than two-lane roads, all else being equal. However, when the number of lanes is increased at the expense of narrower lanes or reduced median width, crash numbers may increase. Median: Both presence of a median and increasing width of the median are associated with fewer crashes. Passing lane: Additional lanes on two-lane roads have been found to reduce crash numbers. Roadside hazards: Among fixed objects hit in run-off-road crashes, bridge pillars, trees, poles, and rock-cuts pose the highest injury risk. Ditches and water are also associated with increased injury risk. Safety zones that are free for hazardous objects reduce the severity of run-off-road crashes. Trees along urban roads: In urban areas, roadside trees may reduce crash numbers. However, a larger distance between the driving lanes and trees is associated with less serious injuries.*

The present report describes results from a literature review of studies of the relationships between cross section elements and road safety. The main focus is on roads similar to typical Norwegian roads in terms of cross section and volume (below 80.000). An analysis of crash statistics on Norwegian two-lane roads is also presented.

Cross section elements covered in the study include:

- Road, lane and shoulder width (mainly on two-lane rural roads)
- Number of lanes
- Median and median width (mainly on multi-lane roads)
- Safety zones.

## Wider roads – fewer crashes

Most studies show that, if all else is equal, including volume and number of lanes, wider roads are associated with fewer crashes. However, this may not be true on roads that already are very wide and on low volume gravel roads.

On Norwegian two-lane roads, the number of crashes decrease by on average 2.5% for each 1 ft. increase in road width. The decrease is greater at higher volumes (Annual average daily traffic, AADT, above 2000). At low volumes (AADT < 1500), increasing width is associated with increasing crash numbers.

## **Wider lanes – fewer crashes**

In most studies, increasing lane width is associated with fewer crashes, all else being equal. However, the results are somewhat inconsistent: Some studies find increasing crash numbers at increasing lane widths, and some studies find non-significant or non-monotonous relationships.

Overall, the results indicate that the safety effects of increasing lane width are most favorable at high volumes. On Norwegian two-lane roads, increasing lane width is associated with decreasing crashes only at volumes above approximately AADT 2300, and with increasing crash numbers at lower volumes.

## **Wider lanes at unchanged road width - more crashes**

When the total road width is constant, most studies indicate that it is more beneficial to have wider shoulders, rather than wider lanes. Some studies found that wider lanes might be more beneficial under certain circumstances, but these circumstances were not consistent across studies. No studies found that wider lanes are generally preferable to wider shoulders when total width remains unchanged.

## **Wider shoulders – fewer crashes**

A large number of empirical studies consistently show that increasing shoulder width is associated with decreasing crash numbers and that paved shoulders are preferable to gravel shoulders.

On average, a 1 ft. increase of shoulder width is associated with a 3.7% decrease in crash numbers (-4.2% on two-lane roads, -2,0% on multi-lane roads). These effects may be somewhat overestimated as not all non-significant results could be included in the analyses.

On Norwegian two-lane roads, a 1 ft. increase of shoulder width by is associated with a decrease in crash numbers by 2.8% on average. The decrease is larger on roads with higher volumes (above AADT 2000).

Results from the literature review show that the positive safety effects of increasing shoulder width are greater:

- At higher volumes than at lower volumes.
- For shoulders that originally are narrow. For shoulders that are approximately as wide as a lane or wider, a further increase of width cannot be expected to reduce crashes. Very wide shoulders can even increase crash severity due to increased speed.
- For single vehicle crashes than for multiple vehicle crashes.
- In crashes that occur in curves, compared to straight sections.

## **More lanes - fewer crashes**

Most studies find that four-lane roads have fewer crashes than two-lane roads, all else being equal. This is mostly due to multi-lane roads often having a higher standard (wider lanes and shoulders, median barriers etc.), but the same type of relationship is also found when other factors are statistically controlled for.

However, when the number of lanes is increased by narrowing the lanes or the median, crash numbers may increase.

These results refer to divided roads. For undivided roads, a relationship between number of lane and crashes has only been found at low volumes. However, on high volume undivided roads, crash numbers tend to increase as the number of lanes increases. In Norway, four-lane undivided roads are generally not used.

## **Divided roads – fewer crashes**

Both the presence of a median and increasing median width is associated with fewer crashes. In rural areas, median divided roads have on average 31% fewer crashes than undivided roads, when other factors, including volume, are statistically controlled for. The safety effects of medians and median width are greater for more serious crashes and greater for head on crashes than for other crashes.

In urban areas, empirical studies found reduced numbers of serious crashes on divided (vs. undivided) roads, but no effects on total crash numbers.

On motorways, increasing median width is associated with decreasing crash numbers, especially when the original median width is below approximately 20 ft. Further increases of median width have only small safety effects, and the effect decreases when original median width increases. Safety effects of increasing median width are also rather small in urban areas.

When comparing roads with about equal total width, wider medians and few lanes are on average safer than narrower medians and more lanes.

## **Passing lanes on two-lane roads - fewer crashes**

Passing lanes, i.e. additional lanes on two-lane roads, have been found to reduce crash numbers. For injury crashes the effect is on average a reduction by 33%. On average, longer passing lanes are associated with greater crash reductions than short passing lanes. Climbing lanes (passing lanes on steep uphill sections, mainly meant for heavy vehicles) have also been found to reduce crash numbers.

## **Roadside hazards – more serious run-off-road crashes**

Safety zones along rural roads that are free from hazardous objects generally reduce the severity of run-off-road crashes. Crash reductions are greater for wider safety zones (up to about 30 ft.), and greater in curves than on straight sections.

Among fixed objects hit in run-off-road crashes, bridge pillars, trees, poles, and rock-cuts pose the highest injury risk. Ditches and water are also associated with increased injury risk when compared to a level roadside without hazardous objects. Steep roadsides increase both the number and severity of run-off-road crashes.

In contrast to rural roads, roadside trees in urban areas may reduce crash numbers. However, increasing the distance between the roadside and trees is associated with less serious injuries in urban areas as well. At urban intersections, both trees and poles were found to increase crash risk and injury risk.