CASE STUDY

RAP PARTNERSHIPS SAVING LIVES

THE SWEDISH 2+1 with wire rope median

iRAP

EuroRAP

2 lanes one way, **1** the other

Reduces head-on crashes

2-star to **3-** or **4-star** rating change

50% fatal & serious injury reductions

3-6 typical Benefit-Cost Ratios

Sweden's 2+1 with wire rope median design has **dramatically reduced head-on collisions** across the world.

Vehicle occupants sustain severe injuries in one of three main configurations – head-on crashes, run-off-the-road and intersection collisions. If one of those risks can be reduced substantially, the threat to life and injury comes down accordingly. Reducing the risk of head-on collisions on inter-urban roads is commonly achieved by providing median separation, often in the form of safety fencing or a barrier. Single-carriageway roads generally demonstrate higher risk than dual-carriageways. This can be because there are typically only painted lines on the road to separate opposing vehicles; it can be too that roadsides and intersections are more hazardous.

WIDESPREAD APPLICATION OF A SIMPLE SOLUTION TO A BIG PROBLEM

Sweden has been instrumental in introducing innovative protection on single-carriageways with the concept of a 2+1 design with median protection. Many existing single-carriageway road sections in Sweden (Figure 1) have been provided with a wire rope safety fence to separate opposing vehicles, thereby effectively making them dual-carriageways, mostly within the existing roadspace required for a single-carriageway. The map at right shows that by 2020 several thousand kilometres of road have been upgraded in this way in Sweden, shown in the map as MML[1] 2+1 and MLV[2] 2+1.

Reduces fatalities and serious injuries by **50%**

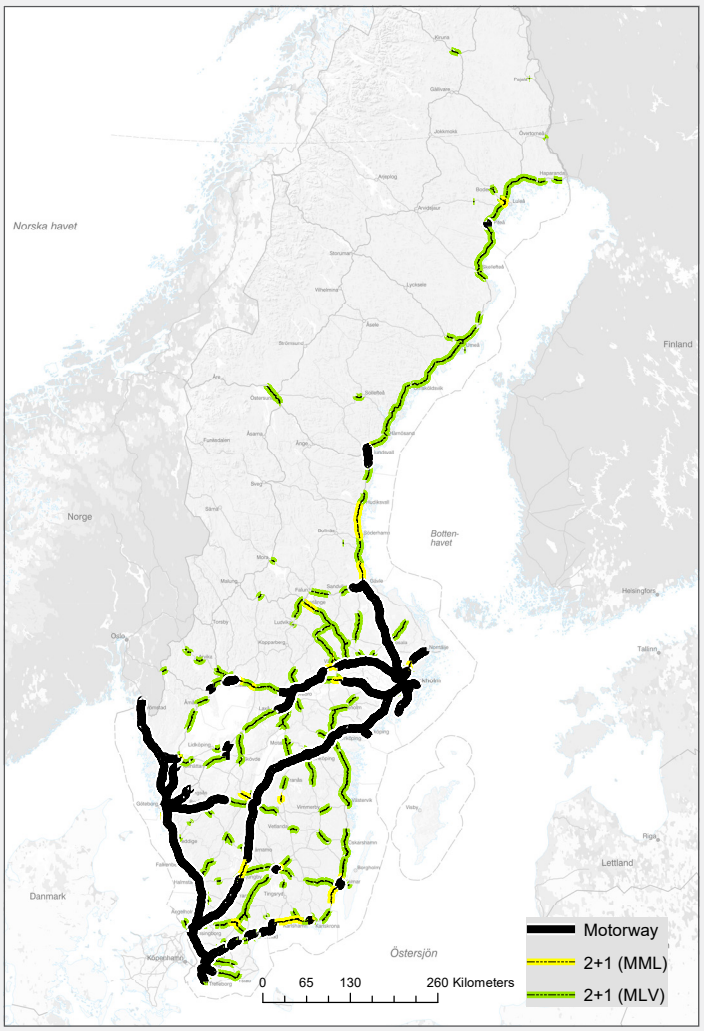
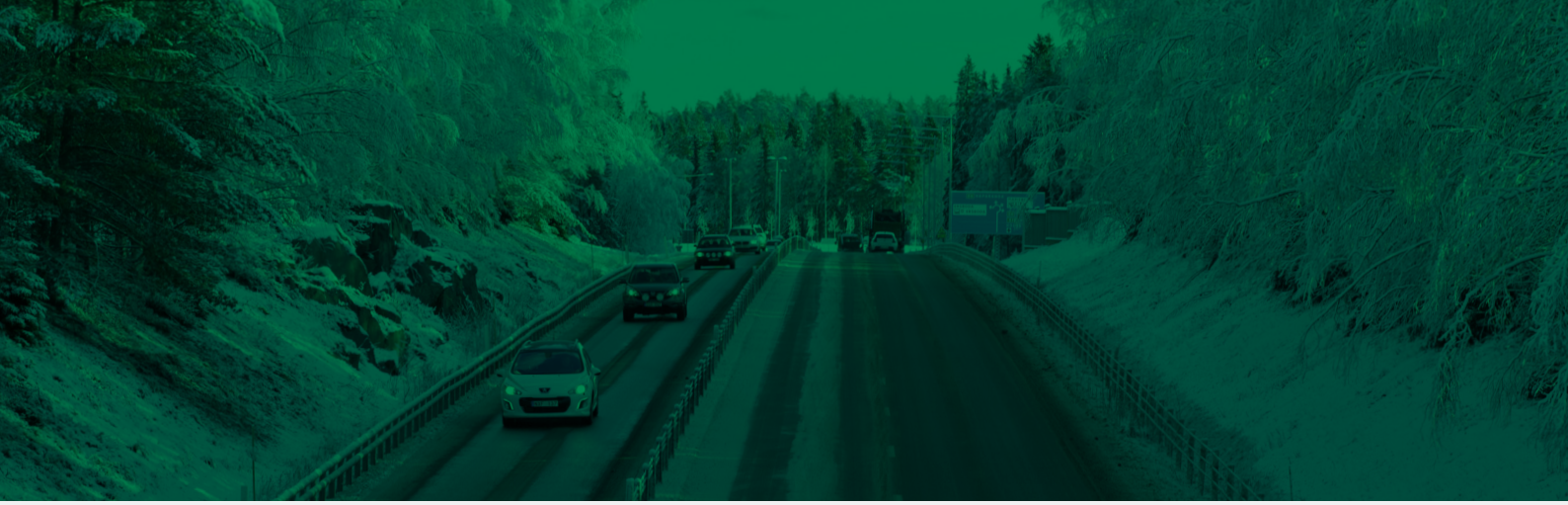


Figure 1: 2+1 with wire rope median road sections in Sweden

[1] MML – "Collision-free" expressway usually with 2+1 lanes and median with a barrier (often wire guardrail). The width is 13 to 14 metres. MML has interchanges with exit- and entry lanes. Slow-moving traffic, cyclists etc. are not allowed.

[2] MLV – "Collision-free" road, generally comprising 2+1 lanes and median with a barrier (often wire guardrail). The width is 13 to 14 metres. MLVs have at-grade intersections with an opening in the median barrier. The cross section at large intersections is usually 1+1 through lanes and with a lane for left-turn traffic. There are also designs with a roundabout.

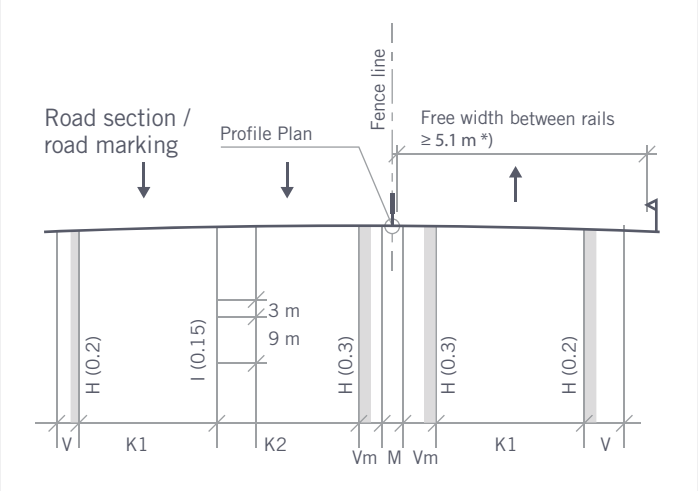


AN EXAMPLE FROM VANNEBERGA

Figures 2 and 3 show a typical "before and after" scenario of a Swedish 2+1, together with mapping of the location where this design has been installed. Lanes alternate, with either 2 lanes or 1 lane in each direction, transitioning alternately after a prescribed distance in order to provide overtaking opportunities in both directions. This 2.4km road section near Vanneberga in southern Sweden (see https://goo.gl/maps/i4J7Xf4SSWGyV6NA8) is carrying approximately 14,700 vehicles per day. A typical cross-section of the 2+1 design is shown in Figure 4.

Figure 2: "Before"

Figure 3: "After"



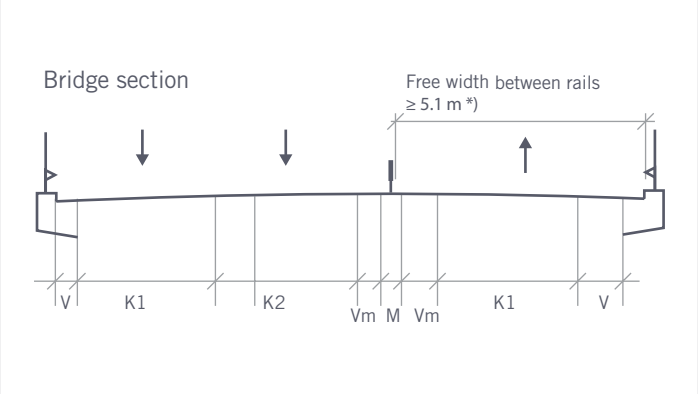
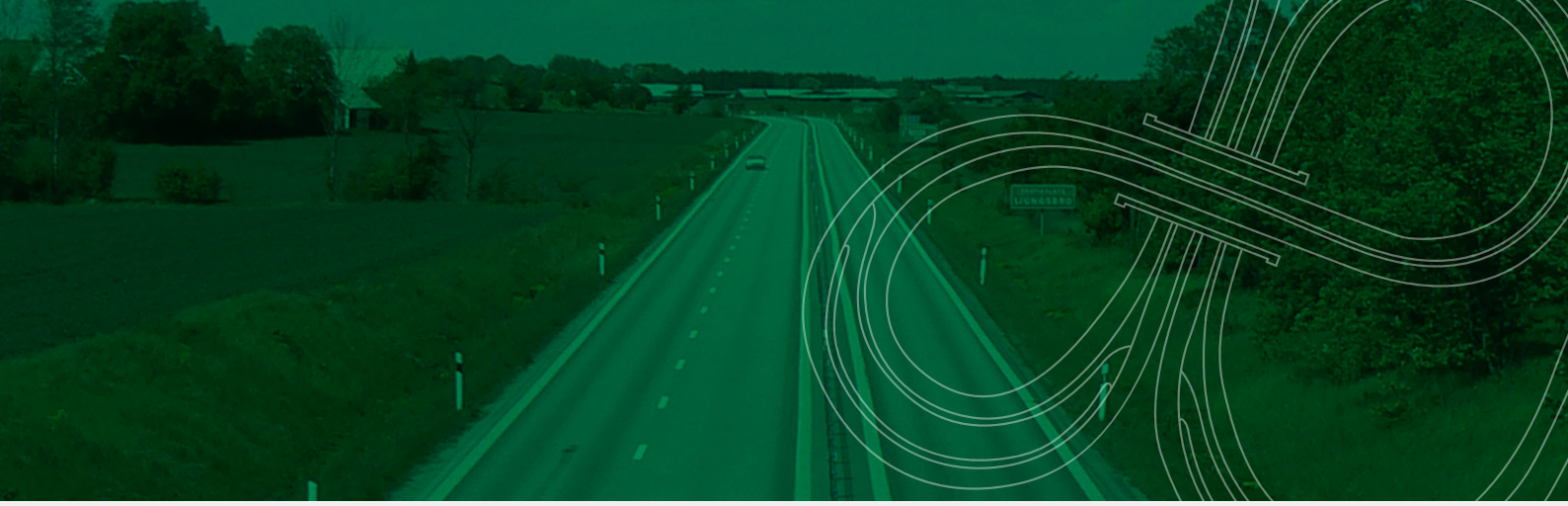


Figure 4: Typical 2+1 cross-section designs and operation (Trafikverket, 2020)



BENEFITS IN CRASH REDUCTION NUMBERS

Researching implementation across Sweden, Vadeby[3] (2016) said:

"Results from the before and after study show a number of significant effects; **the total number of fatalities and seriously injured decreased by 50% and the total number of personal injury crashes decreased by 21%**. The severity consequence (the rate of the number of killed and seriously injured divided by the number of personal injury crashes) decreased by 38%. Looking only at links (excluding intersections), **the number of fatalities and seriously injured decreased by 63% and the personal injury crashes by 28%**. Correcting for regression to the mean gave very similar results."

In earlier work, Carlsson[4] (2009) had tabulated the benefits (Table 1) by speed limit and road type and summarised the findings:

"In summary, **the reduction in FSI (fatal and serious injury)-rate for MML 110 (with a 110km/h speed limit) and Alt-4L 110 (Alternative 4-lane) is 56–58%**, which is explained completely by the corresponding reduction in serious injury ratio. MLV 110 shows the same serious injury ratio but these roads have a lower reduction in FSI (fatal and serious injuries) on links, about 45%, which is the effect of a higher injury accident rate. MLV with 90 km/h has the largest reduction for links – more than 70% – which is due to about 65% lower serious injury ratio and a 25% lower PO-rate. However, for these roads must be added a 70% addition for nodes (junctions), which gives a total reduction more than 60%. This means that the total FSI-rate, including junctions, is the same as that of MML and MLV with 90 km/h. The majority of crashes on collision free roads are run off- and rear end-crashes, which together correspond to 60–80 % of all FSI-accidents. **For other types of crash it can be mentioned that the observed FSI-rate for vulnerable road-users on MLV has been reduced by about 90%** (vulnerable users are not allowed on MML)."

Type and speed limit	FSI-rate		Reduction (%)		SC links	Reduction (%) links
	Links plus junctions	Links	Links plus junctions	Links		
MML 110	0.0219	0.0209	57	56	0.25	58
MML 90	0.0177	0.0146	62	66	0.19	63
MLV 110	0.0305	0.0238	39	46	0.25	55
MLV 90	0.0177	0.0104	63	74	0.17	66
MLV(2+2) 90	0.0195	0.0177	59	70	0.20	58
Alt 4L 110	0.0218	0.0204	57	58	0.25	58
2+1 painted 90	0.0323	0.0250	31	39	0.31	36

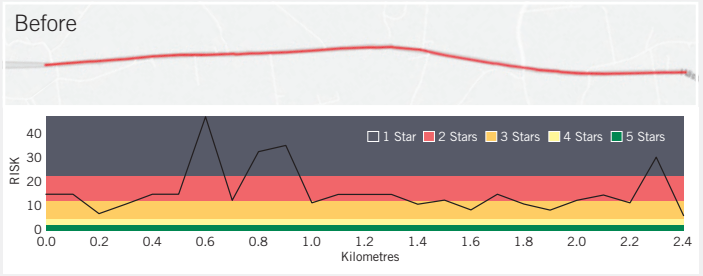
Table 1 The outcome as FSI-rate, total and/or links, and SC/or collision-free roads per Dec. 2006 or Dec. 2007. Comparison with normal rate or ratio for expressways and 13m roads.

AN OBJECTIVE IRAP RISK ASSESSMENT OF THE VANNEBERGA SECTION

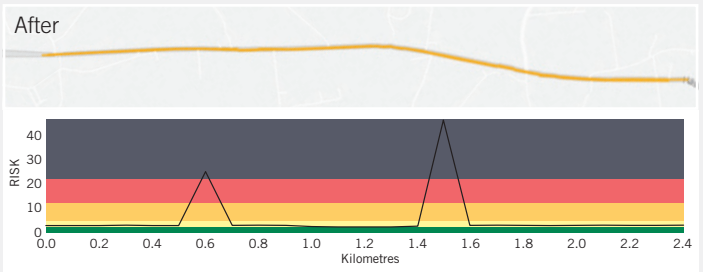
In a country such as Sweden where crash numbers are relatively low, recent crash histories at a location are not a good predictor of long-term risk. At Vanneberga, the 2+1 with median was introduced as part of a large-scale and widespread implementation policy. It was known that over time such action would reduce potential collisions. The implementation was not simply a response to recent crashes.

Independently of this implementation and as an illustration of the safety rating, iRAP has used its model to assess the safety of the Vanneberga case study. It provides a Star Rating for both before and after the installation of the 2+1 with median barrier:

- **Before** upgrade, the road was rated (Figures 5 and 6) as 2-star throughout its length. There were risk spikes at three intersections and smaller risk rises away from these intersections, the latter caused by variation in the safety of the roadside.
- **After** upgrade, the road is rated (Figures 7 and 8) on average at 3-star and as a good 4-star away from the intersections. This improvement is observed despite the speed limit on the road being increased from 90 to 100km/h. Figures 9 and 10 show that the risk of head-on collisions (the yellow in the bar) has of course declined. The roadside risk was reduced in this example by improving the safety of the roadside, for example, by installing safety fencing. Changes were also made to the location and design of intersections.

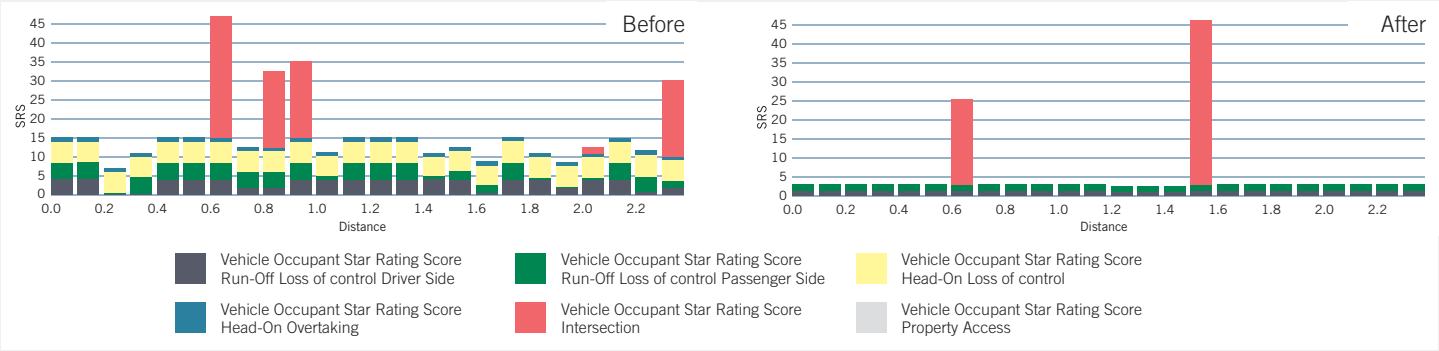


Figures 5 and 6: "Before" – an average of 2-star, with raised risk at intersections and variation in risk on roadsides



Figures 7 and 8: "After" – an average of 3-star, but a high 4-star away from intersections

RISK WORM BY CRASH TYPE



Figures 9 and 10: "Before (left) and After" components of risk showing change in different risk elements

BENEFITS SHARED THROUGHOUT THE WORLD

The Swedish design is much-copied. It can be seen in Spain, Ireland, New Zealand and other countries. iRAP surveys show that installing a wire rope median barrier on single-carriageway roads may have huge benefits. For example, in several of the surveys using the methodology in south-east Europe, the iRAP forecasts show Benefit-Cost Ratios of 3-6 would be achieved with their use and a potential for fatal and serious casualty savings of up to 20 per cent of the total to be saved. Some examples in these and other countries are shown below.

Table 2: Examples of 2+1 with median barrier recommended in iRAP studies

Country	Length of single-carriageway surveyed (km)	Length of 2+1 with wire rope median recommended (km)	Forecast fatal & serious casualty savings in 20 years (rounded)	Average Benefit-Cost Ratio forecast (rounded)	Cost per fatal & serious injury saved (USD, rounded)
Australia	19,756	35	470	1	229,000
Bulgaria	568	335	1,830	3	15,800
Chile	908	46	220	6	26,600
India	17,560	3,369	93,000	4	3,200
Mexico	20,319	40	1,830	5	13,700
Papua New Guinea	3,660	27	8,000	3	6,000
Romania	345	217	1,640	6	12,000

The work of the national bodies in Sweden is notable as good practice on several fronts, for:

- the innovative design thinking behind the 2+1 with wire rope safety fence
- the sharing of the idea with many road authorities around the world
- the rigorous recording and scientific assessment of the efficacy of the design

References

[3] Vadeby, (2016) Traffic safety effects of narrow 2+1 roads with median barrier in Sweden, Traffic Safety on Five Continents, 17th International Conference, Rio de Janeiro, 17-19 May.

[4] Carlsson, A (2009) Evaluation of 2+1-roads with cable barrier, VTI report 636A www.vti.se/publications.

Trafikverket (2020) Krav – VGU Vägars och gators utformning, Publikation 2020:029, section 7.1.2.2 https://trafikverket.ineko.se/Files/sv-SE/71830/Ineko.Product.RelatedFiles/2020_029_vagar_och_gators_utformning_krav.pdf.

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