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Norwegian Public Roads Administration

Automatic section speed control

Results of Evaluation

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Summary
Automatic speed cameras measure average driving speed between two camera boxes.

In 2009 automatic section speed controll trials were conducted at three sites in Norway.

The results show that the average driving speed can be reduced by up to 10% (from approx. 90 km/h to 80 km/h). This effect is dependent on the speed before the average speed cameras were installed.

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Preface

Spot speed enforcement (Automatic speed controll, ASC) using fixed speed cameras was introduced in Norway in 1988. There are currently 360 installations in operation. Despite the limited number of installations, ASC has become a very important traffic safety measure and is an important supplement to the enforcement activities of the police. Measurements that have been taken show that ASC reduces the driving speed from the point at which the driver sees the information sign until several kilometres after the last camera box. The same measurements showed, however, that the speed reduction is not constant between these points and that there is a particularly great speed reduction when passing each camera. The desire to achieve a high, continuous effect between two speed cameras has spurred an interest in testing speed enforcement camera systems (automatic speed section control, ASSC).

In the summer of 2009 the Ministry of Transport and Communications gave the Norwegian Public Roads Administration an opportunity to test out ASSC on two stretches of road. The trial was subsequently expanded by the inclusion of an additional stretch of road. ASSC have more implications for the protection of privacy than ASC. It is therefore particularly important to follow up the effect on the three trial stretches.

This report documents the effect of ASSC on driving speeds on the three trial stretches. An accident reduction effect can only be measured after three to four years of operation. The relationship between driving speed, accidents and the degree of injury is, however, well documented, and speed is thus a good variable for evaluating the expected effect of ASSC on accidents and injuries.

The measurement results have been collected through cooperation between the Southern and Eastern Regions of the Norwegian Public Roads Administration and the Traffic Safety Section in the Traffic Safety, Environment and Technology Department of the Directorate of Public Roads. Senior Engineer Bjørn Brændshøi, Eastern Region, has written Section 7 of the report and taken laser measurements on national road Rv3. Kristian Sakshaug of the Department of Civil and Transport Engineering, NTNU, has conducted the statistical analysis of various speed measurement data, and has written Appendix 1. Astrid Solberg at the Graphics Centre, Eastern Region, has contributed to the design and layout of the tables and figures.

Chief Engineer Arild Ragnøy, has been responsible for evaluating the ASSC trials and has written the report.

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In this document we are using the following abbreviations:

ASC = Automatic speed control, which is the use of a speed camera to control the speed at one point of a road, also known as spot speed enforcement (SSE).

ASSC = Automatic section speed control or speed enforcement camera systems (SPECS), also known as average speed cameras, which is the use of two linked speed cameras to measure the average speed between the two cameras based on time divided by distance.

This document reports on the experiment with Automatic section speed control (ASSC) in Norway

NPRA = the Norwegian Public Roads Administration

Contents

Summary

General

It is well known from research that a reduction in driving speed is a very effective means of increasing traffic safety on stretches of roads where the speed and injury costs are high. Automatic Speed Control (ASC) is one means of reducing the driving speed. This was introduced in Norway in 1988. The speed is checked at one spot on the road, and if the speed is too high, the vehicle and driver are photographed and the police impose a sanction. The working mechanism is based on the fact that the driver chooses to maintain a reduced speed after having passed the camera. Research results show that this effect can be maintained for up to 2–3 kilometres after passing a camera.

If the aim is to achieve reduced driving speeds over longer stretches, then two ASC points can be established that communicate with each other, so that the average driving speed can be calculated between points A and B, known as either average speed cameras or -called automatic section speed control (ASSC). In principle the distance between the two points can be arbitrary, but requirements have nevertheless been defined for the stretch of road that is covered by ASSC.

In order to gain experience with ASSC trials have been carried out at three sites in Norway.

Location (name)	County	Road no.	From section	KM	To section	KM	Length (m)	ADT 2009 both directions (vehicles/day)	Speed limit (km/h)	Number of lanes	ASSC direction	Start date
1 Bakkevann	Telemark	E18	8	1100	8	9700	8600	6500	80	2/3	southbound (1)	June 2009
2 Dovreskogen	Oppland	E6	18	6037	18	11096	5059	3425	80	2	northbound (1)	July 2009
3 Langodden	Hedmark	RV3	14	1340	14	10870	9530	2125	80	2	northbound (1)	May 2010

Table S I: Sites selected to test ASSC

ASSC in brief

On a stretch of road without any major intersections or exits, two ASC points, A and B, are established, and together they monitor the speed on the section between these two points.

At point A, the first point the motorist arrives at, a photo is taken of all vehicles and drivers. The number plates, wheelbase and weight are automatically registered at the same time and sent to point B so that it can recognise the vehicle as it passes this point.

The same vehicle data is collected at point B as at point A. The data registered at point B is compared with the data from point A. If the vehicle is recognised, in other words, we are certain that we have data from the same vehicle that passed point A and B, the passing times are used to calculate the driving time between the two points. When the distance between these points is known, the average driving speed can be calculated. The correct distance of the stretch is verified by the Weights and Measures Authority and the police.

If the driving speed is too high, then the photo and data in question are sent from point B to a central server at the NPRA and a message to do the same is sent to point A. The data and photos that can identify the vehicle and driver are then deleted from both points. If the vehicle has observed the legal speed limit or was never recognised, the photos and data will also be deleted.

ASSC has been developed through close cooperation between the police and the NPRA. The Data Protection Agency has been informed about the progress of this work. The latter agency has contributed to safeguarding personal privacy. ASSC should have the same high level of privacy protection as conventional ASC.

An absolute requirement of the Data Protection Agency and the police is that information signs clearly state whether the cameras are ASC or ASSC. With average speed cameras, a sanction is imposed only for an average driving speed that is too high between the cameras, and not when the motorist has driven too fast when passing point A or point B.

Data collection

Three types of equipment for measuring speed have been used to collect data at the three trial sites.

- Conventional radar, where the results are accumulated and presented as average hourly values.
- WIM (weight in motion) cables (two cables directly across the road), which make it possible to weigh the axles and measure the wheelbase in addition to measuring the speed.
- Tests have been conducted with the use of laser speed guns to measure the driving speed before and after a camera.

The changes in speed should in general be shown by a before-and-after analysis. Depending on the particular problem and the practical conditions, different equipment has been used for different types of measurements.

Criteria measurements are measurements taken on the stretches to determine whether the criteria for establishing ASSC were satisfied. The measurements are taken continuously for a week on the most representative part of the section. These measurements are made with radar and provide hourly values for a section. The measurements are taken before the camera boxes are installed and can be used as supplemental measurements of the situation prior to implementing ASSC.

Speed measurements for ASC generally use WIM cables. In addition to measuring speed, the wheelbase and axle weight are also measured. Such equipment was installed before the camera boxes were established at both point A and point B. By means of the information stored on the individual vehicles, some of the vehicles can be recognised at point A and point B so that the average speed in the situation before ASSC. In the situation after ASSC has been implemented, anonymous information is stored on the vehicles that have passed. This enables a before-and-after analysis of the driving speed at each of the points and for the section of road as a whole. After ASSC has been established, anonymous results from point A and point B are stored (i.e. without a photo and registration plate number). These measurements are made with WIM cables, and information on the individual vehicles is stored. Average speeds can then be calculated for the vehicles that are recognised at both points. The measurements from the situation after ASSC have been established can also be used to illustrate the problem of extreme speeds for motorists that are registered at only one of the points.

Supplemental speed measurements before box A, between point A and point B, and after box B are made using radar and give the average hourly speeds. These measurements are carried out **after** the camera boxes have been installed. These measurements cannot recognise the individual vehicles and can therefore not be used to calculate average speeds for the section of road.

Evaluation of average speed cameras (ASSC) answers many questions

Reference is made to the main problems and the answer to these as they have been reviewed in this report.

How great is the reduction of the average speed?

This question has been answered for all three stretches that have been included in the trial. Bakkevann and Dovreskogen are the locations where the changes have been measured by means of radar. Of these three locations, the speed before ASSC is the lowest at Bakkevann, and the reduction as a result of ASSC is therefore the lowest here. As is the case with ASC, a clear connection has been noted between the speed level before ASC and the speed reduction after its introduction.

At **Bakkevann on the E18** the average hourly speed is reduced by 2.7 km/h, from 76.7 km before ASSC to 74.0 km/h ten weeks after ASSC was established. This reduction remains stable 25 weeks after the installation.

At **Dovreskogen on the E6** the average speed is reduced from 89.4 km/h before ASSC to 80.6 km/h after the installation of the ASSC. This is a reduction of 8.8 km/h. The percentage of motorists who drive faster than the speed limit of 80 km/h declined from 90.5% before to 52.7% after installing ASSC. The corresponding percentages that drive faster than 90 km/h are 42.3% and 9.4%, respectively.

At **Langodden on Rv3**, where the speed was 88.5 km/h in before ASSC, the average speed was reduced by 10.2 km/h. The reduction on this section was identified by means of a before-and-after analysis based on WIM cables in the road (as used in ASC). The reduction at points A and

B is greater than for the section as a whole. At point A there is a reduction of 14.1 km/h, from 89.0 km/h to 74.9 km/h. The greatest reduction of 18.0 km/h is at point B, from 90 km/h to 72.0 km/h.

At Langodden the number of motorists who drove faster than the speed limit sank at the same rate as at Dovreskogen.

Is the speed reduction for the section as a whole as great as at each of the points?

Here we have a clear result for all the measuring points and time periods. The speed reduction is greater at each of the cameras than for the stretch of road between the boxes. The greatest reduction is at camera box B.

At Langodden on Rv3, a speed reduction of 14.1 km/h was registered for point A and 18.0 km/h for point B, while a reduction of 10.2 km/h was registered for the section as a whole.

The results are similar for the other sites and time periods that were tested.

Do the motorists who are registered at only one camera drive faster or slower than those who are recognised at both points?

Since it is only the average speed that forms the basis for possible sanctions (it is not enough just to pass the camera(s) at too high a speed), it has been very important to establish that there are no systematic differences in the driving speed at the camera boxes for those who are recognised at one or both points, respectively. Those who are registered at only one point do not have a significantly different driving speed than those who are recognised at both points. The deviations range from -1.5 km/h to +2.2 km/h. The results are based on more than 125,000 vehicle passings.

Do motorists drive significantly faster on a spot in the middle of a section than the average section speed indicates?

Since the speed reduction observed at the cameras is greater than the average on the section of road as a whole, the speed measured at a point approximately in the middle of the section will be somewhat higher than the corresponding average speed. Calculated as an average from Dovreskogen on the E6 and Langodden on Rv3, the speed is 75.1 km/h at box A, 72.6 km/h at box B and 80.1 km/h at point M in the middle of the section of road. At the same time the average speed is 78.4 km/h. This means that the speed at a point in the middle of the section is around 2% higher than the speed for the section of road as a whole.

How far after the last camera is the speed reduced?

Our radar measurements after the last camera has been passed cover a distance of 1,500 metres. Here the driving speed at Dovreskogen on the E6 is measured to be 17.1% higher than when passing point B (83.4 km/h versus 71.2 km/h). We cannot rule out the possibility that the speed is still influenced by the cameras, since the speed from the time before ASSC was installed was somewhat higher than this (89.4 km/h measured by radar at one point). However, the change in speed from 1,000 m after the camera to 1,500 m after the camera is small. A conservative interpretation is therefore that the speed is influenced for at least 1,000 m after point B has been passed.

How many motorists brake at the cameras?

Simple measurements of whether the brake lights come on show that around half the motorists touch the brake pedal in the immediate vicinity of (about 50 m before) point A. However, laser measurements show that the speed reduction is slight.

Conclusion

ASSC appears to be an effective and powerful means of achieving a significant reduction in driving speeds on sections of road where the speed is initially higher than the speed limit. The size of the reduction is dependent on the driving speed before the implementation of ASSC.

Compared with conventional ASC consisting of two camera boxes at a distance of around 10 km from each other, calculations show that average speed cameras are significantly more effective, with a reduction of the driving speed and an associated reduction in injury costs that is up to three times as great.

The percentage of motorists who still drive faster than the speed limit is higher for the average speed camera installations we have evaluated as for conventional ASC. The results may indicate a lack of understanding of how the system works. Information to motorists may further increase the effect.

Our technical operational experience using ASSC has been good.

1. Why average speed camera speed enforcement systems?

1.1 Background

Conventional ASC or spot speed cameras were introduced in Norway in 1988. The aim was, and still is, to reduce the number of accidents and the scope of the injuries resulting from these accidents. There are currently 360 operational camera boxes distributed throughout Norway. The working mechanism is simple. By getting motorists to reduce their driving speed, the number of accidents and the seriousness of injuries sustained in an accident will be reduced. This correlation is widely known and well-documented through, for example, the "power model" (Elvik, 2009).

The Institute of Transport Economics (TØI) carried out a major project in 1999-2000 on assignment from the Ministry of Transport and Communications in order to document the effect of conventional SSE on driving speed, and to examine other issues related to speed adaptation (Ragnøy, 2002). The effect on driving speed was measured (as a change in the average hourly speed) at the actual ASC cameras and at points between two cameras before (one year before) and after (one year after) the cameras were put into operation.

The main result from this survey was the fact that the driving speed was reduced by at all the points where measurements were taken. More specifically, at each of the 20 ATC points a change in speed (corrected for any change in the reference points) of between -1.4 km/h and -7.1 km/h was registered. At measurement points without ASC, between two ASC cameras, the driving speed was reduced, but the effects were clearly less here. Examples of such results from E18 in Østfold are illustrated in figure 1.1.

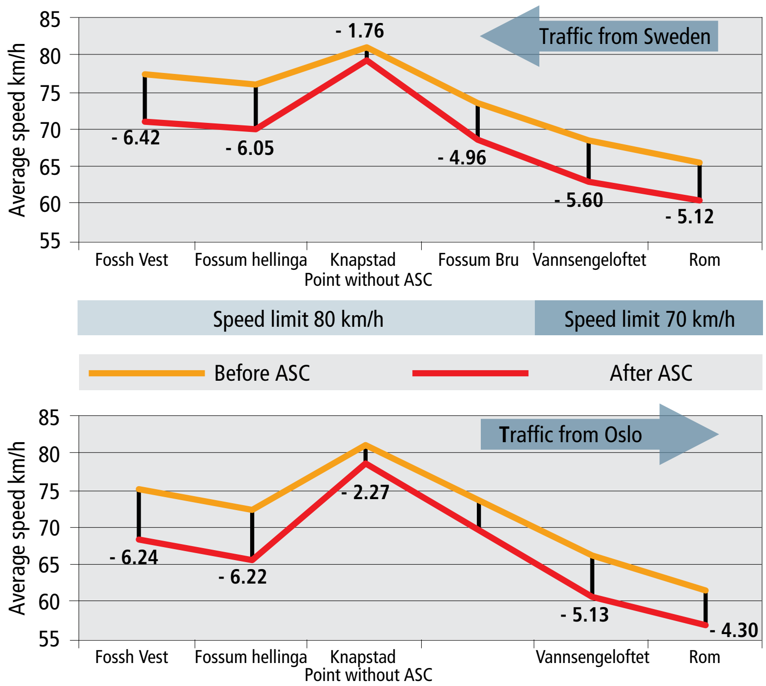


Figure 1.1: Average hourly speed (spot speed) before and after installing ASC. Change in average speed in km/h. E18 Østfold.
Source: TØI Report 573/2002

All points in figure 1.1 have ASC, except for the Knapstad point in the middle of the figure. The two parts of the figures each refer to their own driving direction. At the ASC points the change in speed is calculated to be between -4.3 km/h and -6.4 km/h. At Knapstad, which is before the next ASC point, the change in speed has been calculated at -1.8 km/h in the direction from Sweden and -2.3 km/h in the direction from Oslo. The distances from the ASC points to the measuring point at Knapstad are 4,750 m (traffic from Sweden) and 3,250 m (traffic from Oslo) calculated in the driving direction.

Even though a reduction in speed is evident at all the measuring points in the figure, a continuous effect will not be maintained if the distance between cameras is too long.

Similar results were found on the E6 in Hedmark.

1.2 Mode of operation for ASC

Since the traffic safety effect is based on a reduction in speed, this effect will depend on how great a reduction in speed is achieved by means of the speed cameras. The reduction in speed that is achieved is a function of the driving speed before ASC is installed.

All effective traffic safety measures will have a greater impact at a site where the traffic safety is poor than at a site where it is good. Some of this impact may be attributed to regression effects, but even when correcting for this, the measures will generally have a greater impact (percentage-wise) at sites where the initial traffic safety situation is poor.
The traffic safety effect of ASC is thus a function of both the speed and the scope of accidents and injuries in the situation before ASC is installed. To ensure that ASC becomes a successful traffic safety measure, the driving speed and scope of injuries are included in the criteria for where ASC can be used. In short, both the speed and the incidence and severity of accidents should be higher than normal.

The effect of ASC is clearly linked to a reduction in the driving speed **for the section of road where the camera box is located**. In order for spot speed cameras to have a traffic safety effect, it must be assumed that the reduction in speed at the camera will be maintained for a while after the camera has been passed. Normally this effect is assumed to last up to 2.5–3.0 km after the camera box has been passed. In a system with multiple camera boxes, where the driving speed is reduced more at the camera box than in the middle between the cameras, the traffic safety effect will vary in step with the change in speed. If the distance between two camera boxes is greater than the effect of one camera box, then the traffic safety effect will also cease for a certain section of road between two camera boxes.

At locations where the aim is to improve traffic safety and reduce the driving speed over longer sections of roads, it will be necessary to install a large number of cameras (about every 2.5–3.0

km). Alternatively, the cameras can communicate with each other and thus measure the average driving speed for the entire stretch of road between the boxes.

The NPRA has not performed any new measurements in recent years of how far the effect can be traced after a single ASC camera.

1.3 Greater requirements for the effectiveness of traffic safety work

Since the accident risk has decreased from year to year, it has become increasingly difficult to reduce this risk even further. Measures that could have had a relatively large impact on traffic safety previously, have less effect today. This makes traffic safety work more challenging. (See also the use of conventional ASC.) To increase the effect of ASC, we can introduce speed enforcement camera systems, or average speed cameras.

The purpose of installing average speed cameras is:

- to maintain a high effect on the entire stretch of road between two camera boxes
- to reduce braking and acceleration at the actual camera box

The goal is to achieve the same effect as a conventional ASC camera on the entire section of road between two cameras and thus contribute to a greater reduction in accidents than using conventional ASC, while reducing some of the undesired side effects of ASC.

2. Speed enforcement camera systems (ASSC) or average speed cameras

2.1 About the system

In the wake of the development of digital cameras, plans for a ASSC project were established already in 2002. However, it was not until as part of the project "Traffic Safety Lillehammer - keeping our sights on Vision Zero" that work on developing a ASSC system based on the measurement of the average driving speed on a section of road between two measuring points really began to take shape.

On a section of road without any major intersections or exits, two cameras are installed at points A and point B, and together these two points monitor the speed on the section of road between the points. At point A, the first point the motorist arrives at, a photo is taken of all vehicles and drivers. The number plate, wheelbase and weight are automatically registered and sent to point B for recognition of the vehicle (as it passes this point).

The same vehicle data is collected at point B as at point A. The data registered at point B is compared with the data from point A. If the vehicle is recognised, in other words, we are certain that we have data from the same vehicle that has passed at both points A and B, the passing times are used to calculate the driving time between the points. When the distance between the points is known, the average driving speed can be calculated. The correct distance of the stretch is verified by the Weights and Measures Authority and the police.

If the driving speed is too high, the relevant photo with data is sent from point B to a central server at the NPRA and a message to do the same is sent to point A. The data and photos that can identify the vehicle and driver are subsequently deleted from both points. If the vehicle has observed the legal speed limit or was never recognised, the photos and data are immediately deleted.

ASSC has been developed through close cooperation between the police and the NPRA. The Data Protection Agency has been informed about the progress of this work. The latter agency has contributed to safeguarding personal privacy. should have the same high level of privacy protection as conventional ASC.

An absolute requirement of the Data Protection Agency and the police is that information signs clearly state whether the cameras are ASC cameras or ASC cameras. With ASSC only an average driving speed between the cameras that is too high is subject to sanctions, and not whether the motorist drove too fast when passing point A or point B.

In order for motorists to be informed immediately that they have been registered at a speed that is too high, a conventional traffic light has been installed after the last camera that will blink yellow if the average speed has been too high.

Figure 2.1: Example of an information sign for ASSC

2.2 Special challenges

Given the way the ASSC works and the Data Protection Agency's strict requirements for the protection of personal privacy, there are several major challenges that must be solved in a satisfactory manner before ASSC can be used on a larger scale in the future.

For ASC a high quality photo of the driver and the vehicle's number plate is required. The photo is taken after it has been established that the vehicle has a driving speed that requires sanctions. Thus the motorist is not photographed until after he or she has committed an offence.

2.2.1 Large number of photos with flash

With ASSC the average driving speed is measured over a section of road between points A and B for everyone who passes this section. Therefore a photo must be taken of both the number plate and the driver at a point in time when it has not been ascertained whether the motorist has committed an offence. All passing vehicles and drivers are photographed. Clear photos of the vehicle's number plate and the driver's face must be taken at both points. The actual average speed is calculated after the photos are taken. If a sanction is to be imposed, then the photos must be kept. If not, then both photos (from point A and point B) must be deleted immediately. Due to variable light conditions, it is necessary to use a flash when taking photos at the two points. The technology required is a challenge, because it must be able to withstand a large number of flashes in order for the system to work in a satisfactory manner without the operating expenses being too high. The flash must also be visible as little as possible in order not to bother the motorists. This has been achieved by developing a flash with light in the infrared spectrum, which in theory is not visible to the human eye. A weak flash will nevertheless be visible, since the flash has a relatively high effect in order to provide adequate light in all weather conditions.

2.2.2 Verifiable and credible routines for the deletion of photos

A key requirement for ASSC and ASC for the Data Protection Agency has been to ensure the protection of the motorists' privacy. The difference between ASSC and ASC is the fact that the ASSC take photos of motorists who have not committed an offence. These photos must not be stored or copied. When developing ASSC, it has therefore been of decisive importance to the Data Protection Agency to ensure verifiable and credible routines for the deletion of all data and photos of motorists who have not committed an offence.

The system is designed so that personal data never leaves the camera boxes until excessive speed has been identified for the vehicle in question. This simplifies the work of deleting the data permanently, since the data has not been sent from the boxes. The deletion of personal data occurs when a motorist drives legally past the cameras or when a vehicle is not recognised by both cameras.

The data is sent to a server only after it has been ascertained that the speed is so high that it must be subject to sanctions. In addition, monitoring routines have been developed to continuously ensure that no unwarranted personal data is stored in the camera boxes or on the server.

2.2.3 Automatic recognition

Photos from both points are taken automatically of all passing vehicles, and the system must recognise the vehicle after passing point B in order to calculate the average speed. However, recognition of the vehicle after passing point B (”pairing” the photo with data taken at point A and point B) must be carried out automatically in order for the system to function. This is accomplished by means of the data registered from sensors in the road. These are pressure-sensitive and are used to measure the vehicle’s speed, wheelbase and weight. The passing time at both points provides the basis for calculating the average speed on the particular section of road.

Recognition of the vehicle is carried out by means of an automatic process that is based on the registered data. The challenge here is that the system, in order to be fair and credible, must recognise a relatively high number of the vehicles that pass both points and keep the number of mismatches as low as possible.

It is important to emphasise that no drivers can be wrongfully subject to sanctions as the result of ASSC. Ultimately there is an operator who verifies that the photos from point A and point B show the same car and driver. This is a manual check of the automatic recognition process.

However, in the interest of due process it is also important that a large percentage of those who actually drive too fast on the section are recognised and subject to sanctions when the system is active.

2.3 Relevant problems

Given the outlined system and the description of how it works, along with the associated challenges and limitations, we have designed a measurement system with a view to illustrating the following problems.

2.3.1 Reduction of the average speed

The primary objective of ASSC is to reduce the average driving speed on the section of road between cameras at points A and B. The main result from this evaluation will therefore be to demonstrate the magnitude of this change.

This can be done by comparing the results from speed measurements taken before and after installation of ASSC either by means of radar measurements on a representative section of the road or by comparing the measured average speeds.

- **How great is the reduction of the average speed?**

2.3.2 Measuring speeds at points A and B

One of the objectives of average speed cameras is to achieve approximately the same effect on the section of road between A and B as at each of the cameras. Therefore corresponding before and after measurements must be taken at each of the two cameras, as mentioned above. These results are then compared with the measured average speeds from section 2.3.1.

The Data Protection Agency and the police point out that a ASSC system must only be used for sanctions against an average driving speed on the stretch of road in question. In practice this means that the cameras (both A and B) can be passed at speeds significantly over the speed limit without resulting in any sanctions if the average driving speed is nevertheless lower than the speed limit. It must be determined whether those who have not been recognised at both cameras have a tendency to have a higher or lower driving speed than average when they pass camera A or B. It is therefore important to divide the motorists into two groups and to differentiate between those who have been recognised at both cameras and those who are recognised at only one of the cameras. Recognition means the recognition of the vehicle by its weight and wheelbase.

Those who are recognised at points A and B

Here both the average speed and the speed at each of the cameras is measured, individually and as a group. Comparisons can be made of the speed at points A and B with the speed on the entire section of road from A to B.

- **Is the speed reduction for the section as a whole as great as at each of the cameras?**

Those who are not recognised at points A and B

It is not possible to calculate the average speed for vehicles that are not recognised at both cameras. It is not possible to impose any sanction on this group either. Comparison of the speed of this group at the cameras with the group that has been recognised at both points (and which may have been subject to sanction) is therefore of great interest. The observation of any extreme speeds among those who are registered at only one camera is very decisive for the overall evaluation of ASSC.

- **Do the motorists who are registered at only one camera drive faster or slower than those who are recognised at both cameras?**

2.3.3 Measuring speeds between the cameras

Any change in speed on the section of road can be determined in the after situation by comparing the calculated average speed with the speed measurements taken on the section of road.

- **Do motorists drive significantly faster on a section in the middle between the cameras than the average speed indicates?**

2.3.4. Speed measurements after the last camera

Conventional ASC has an effect after the camera box has been passed. This has to do in part with the motorist's respect and understanding of the rules/norms, but also with the fact that they are not sure whether they have passed the last camera, or whether another one will appear soon. For ASSC the distance is signposted and the motorists can thus be relatively sure that there will be no more cameras immediately after passing the last camera. In order to evaluate whether ASSC has an effect for the same or a longer distance than spot speed cameras ASC, speed measurements must be taken downstream from the last camera.

- **How far after the last camera is the speed reduced?**

2.3.5. Measurements with a laser speed gun or registration of brake lights

One of the drawbacks of ASC is the fact that motorists have a tendency to reduce their speed and to brake near the camera box. Since it is only the average speed that is subject to sanctions, this should strictly speaking be unnecessary with ASSC. In order to investigate this problem, speed measurements should be taken using a laser speed gun near the cameras. Alternatively, and as a minimum, a simple count of ”brake light use” should be made.

- **What percentage of motorists brake near the cameras?**
- **What are the speed profiles 100 m before and after the first camera box?**

3. Trial sites

3.1 New guidelines for selecting sections of road

The ”Guidelines for selecting sections of road for automatic speed control (ASC)” were revised prior to the trials.

Like the previous criteria, the latest version (Public Roads Administration & Police, 2009) is based on the fact that the average driving speed on the section (measured over one week) must be higher than the speed limit at the location, and the accident situation (measured as the injury costs) must be more than 30% higher than what is normal for similar sections in Norway.

As a basic rule, both these criteria must be satisfied. However, this requirement has been adjusted somewhat, so that ”If one of the criterion has not been satisfied, but the other criterion has been satisfied by a good margin (more than 20%), the value of an anticipated reduction in the injury costs by establishing automatic speed control can be calculated. As a minimum this reduction in costs must be higher than the cost of establishing, operating and maintaining the automatic speed control system.”

The criteria have also been expanded to include the following that directly concern the use of ASSC:

- Control section 2–10 km.
- Same speed limit for the entire control section
- The control section must have a geometry (both horizontal and vertical) that does not place limitations on driving faster than the speed limit on any section of the relevant section of road.
- The control section must not have any intersections or exits with an AADT > 250.

3.2 Selection of sections

The selection of sections for testing ASSC has been made in close cooperation between the NPRA and the police. This cooperation has been of decisive importance since this trial is regarded as an pilot. Further development of ASSC is dependent on the results from this trial.

Emphasis is placed on satisfying the criteria to the greatest possible extent when the selection is made. Since this is regarded as a pilot, emphasis has also been placed on the section in question having a practical location with regard to power supply, communication (data lines) and accessibility. Emphasis has also been placed on the sections of road being located in different counties in order to achieve a geographic spread. Three stretches of road have been chosen for the trial. These sections are illustrated in table 3.1.

Location (name)	County	Road no.	From section	km	To section	km	Length (m)	ADT 2009 both directions (vehicles/ day)	Speed limit (km/h)	Number of lanes	ATC direction	Start date
1 Bakkevann	Telemark	E18	8	1100	8	9700	8600	6500	80	2/3	southbound (1)	June 2009
2 Dovreskogen	Oppland	E6	18	6037	18	11096	5059	3425	80	2	northbound (1)	July 2009
3 Langodden	Hedmark	RV3	14	1340	14	10870	9530	2125	80	2	northbound (1)	May 2010

Table 3.1: Information on the sites selected for the testing of ASSC.

The table shows the road number, length of the section, AADT (combined for both directions), speed limit, and date for the start-up of the ASSC.

4. Data collection and methods

4.1 Equipment

Three types of speed measurement equipment are used for data collection at the three sites.

- Conventional radar, where the results are accumulated and presented as average hourly values.
- WIM (weight in motion) cables (two cables directly across the road), making it possible to weigh the axles and measure the wheelbase, in addition to speed measurement. Depending on the storage medium, such results can be stored for individual vehicles and for speed measurement as average hourly values.
- Experiments have been made with the use of laser speed guns to measure the driving speed before and after a camera.

4.2 Measurements

The measurements are carried out using specific equipment for different purposes. Changes in speed should in general be established by a before-and-after study.

4.2.1 Criteria measurements

Criteria measurements are measurements made on the section to determine whether the criteria for installing average speed cameras were satisfied. The measurements were taken continuously for a week on the most representative part of the section. These measurements were made using radar and provide hourly values. The measurements were taken before the cameras were installed and can, in addition to other measurements, be used as supplemental measurements of the situation prior to ASC.

4.2.2 Measurements with Datarec/ASC equipment/WIM cables

Automatic speed control normally uses WIM cables to measure speed, wheelbases and axle weights. The results from individual vehicles are processed and stored in a computer (Datarec) located in a small cabinet on the side of the road (next to the camera). This equipment is installed before the cameras are installed at both point A and point B. By means of the information gathered about the individual vehicles, some of the vehicles can be recognised at point A and point B so that the average speed prior to installing ASSC can be calculated.

4.2.3 Measurements between the cameras before point A and after point B

Supplemental speed measurements before point A, between point A and point B, and after point B are made by radar and give the average hourly speeds. These measurements are carried out after the cameras have been installed. These measurements cannot recognise the individual vehicles and can therefore not be used to calculate average speeds.

4.2.4 Operational statistics

After ASSC has been established, anonymous results from camera point A and camera point B are stored (i.e. without a photo and registration plate number). These measurements are made using WIM cables, and information on individual vehicles is stored. Average speeds can be calculated for the vehicles that are recognised at both cameras.

In addition to representing data from the after situation, operational statistics can also be used to illustrate the problems associated with extreme speed by motorists that are registered at only one of the camera points.

Table 4.1 illustrates what measurements are carried out at each of the three sites.

Location (name)	County	Road no.	Start date	Criteria measurement	Separate before measurements	After measurements	Supplemental measurements before, after and between A and B (in the after situation)
1 Bakkevann	Telemark	E 18	June 2009	radar	no	Operational statistics + radar	no
2 Dovreskogen	Oppland	E6	July 2009	radar	no	Operational statistics + radar	Radar
3 Langodden	Hedmark	RV3	May 2010	radar	WIM point at A, B and a point approxi-mately in the middle between A and B	Operational statistics	Radar and established WIM – point approximately in the middle between the camera boxes

Table 4.1 Measurements carried out with ASSC on the three sections of road.

As the table shows, comprehensive measurements have not been carried out at Bakkevann. Here the criteria measurements carried out by radar can be used as before measurements. In addition, data from the operational statistics could serve as after measurements. The statistics can be used in connection with any extreme speed by those who are registered at only one camera.

Separate before measurements have not been carried out at Dovreskogen either. However, supplemental radar measurements have been carried out here. This is to illustrate the problem associated with the speed before (prior to) the ASSC section of road and the duration (length) of any reduction in speed. Otherwise the possibilities are the same as at Bakkevann.

The most comprehensive collection of data has been carried out at Langodden on Rv3 near Alvdal. Here, separate measurements have been carried out at both measuring points (future camera locations) with WIM cables. This entails individual vehicle measurements that make it possible to recognise and calculate the average speed on the section in the before situation. In addition, a fixed WIM point has been established in the middle of the section of road. The operational statistics provide data from the after situation, where radar measurements have also been carried out before and after passing the ASSC section of road..

4.2.5 Regarding differences in the measured driving speed

To determine whether the average driving speed at a point or on a section has changed, for example, from before to after the introduction of ASSC, statistical models are often used to calculate the *level of significance*. The level of significance means the likelihood that the two average values are nevertheless the same, after we have concluded that they are *not,* based on our calculations and criteria. A difference is said to be significant if this likelihood is less than a certain level; normally 5%.

How the level of significance is calculated for the difference between two average speeds is explained in Appendix 2. It can be seen there that the more vehicles the averages are based on, and the more the individual speeds are concentrated around the mean values, i.e. the lower the *distribution*, the less the difference between the two average speeds needs to be before it becomes significant.

For automatic speed measurement, a large percentage of the vehicles that pass a measuring point or a section of road will be registered. This generally means that the average values are based on a relatively large number of vehicles, often several thousand. This also applies to the speed measurements that form the basis for the evaluation of the change in speed before/after the establishment of ASSC in this document. This means that any changes in speed as low as 0.1-0.2 km/h will be significant. The question is, however, whether these small differences can be attributed to the introduced measure (here ASSC) or are due to other circumstances.

Since the measurement series that are used are very large, even the smallest differences in the average speed will be significant for the number of vehicles measured when evaluating changes in speed upon the establishment of ASSC. However, this does not automatically mean that has caused a significant change in the speed level.

If we compare the average speed in the same week for two subsequent years where the AADT is around 2000, it is not uncommon to see differences in the average speed of around 2 km/h during the summer. During winter the differences will often be much greater. These differences are attributed then to significant differences in the weather and road conditions from year to year, and in the composition of the traffic. This is illustrated in Appendix 1.

In order for a change in the driving speed to be linked to the measures that are implemented, the change should be greater than what could normally occur as a result of natural causes.

Since "any" difference in the average speed is significant, including differences that probably cannot be attributed to the establishment of ASSC, we have not seen any benefit from performing significance calculations. However, the magnitude of the changes that are calculated in this report is generally so great that they can be said with certainty to be associated with the establishment of ASSC.

5. Results – Effect on speed

5.1 Before-and-after study

5.1.1 E18, Bakkevann

Figure 5.1 illustrates the results from the before-and-after study performed on the automated speed enforcement section in Bamble. The measurements have been carried out by radar on a cross-section of the E18, (section 18; km 6,250) and comprises around 260,000 vehicles. The speed limit is 80 km/h. The location of the ASSC cameras is indicated on the figure. Measurements were carried out in week 26 (before ASSC), in week 36 (10 weeks after installation) and in week 51 (after 25 weeks). The measurements were taken on the same weekdays (Wednesday and Thursday) in each time period. Midweek days were purposely chosen for this section of road since there is heavy weekend traffic here, with congestion and a lot of mutual dependencies between vehicles.

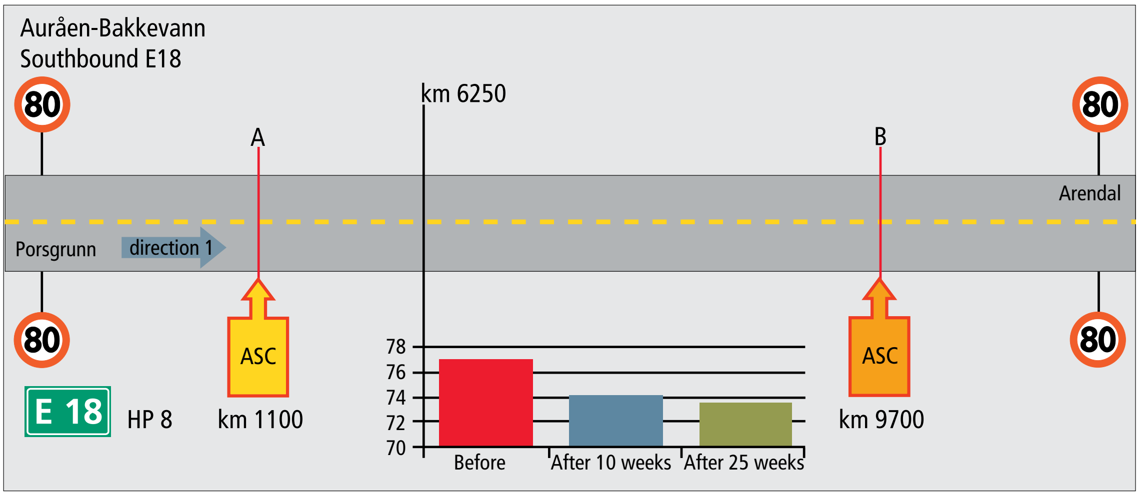
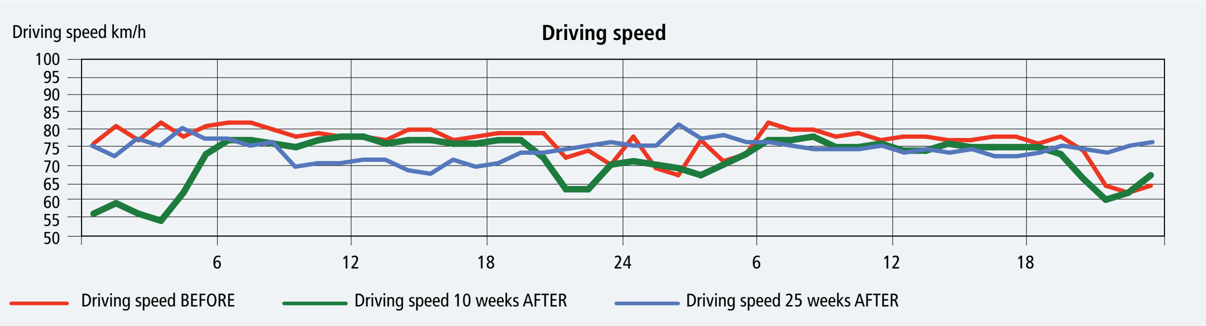


Figure 5.1 Before-and-after study of ASSC at Bakkevann, E18. Driving speed in km/h on representative section before and 10 and 25 weeks after the installation of ASSC.

The average hourly speed is reduced by 2.7 km/h from 76.7 km/h before ASSC to 74.0 km/h ten weeks after installing the cameras. After 25 weeks the speed is reduced to 73.6 km/h. There is no change in the driving speed during the corresponding time period in the opposite traffic direction, where ASSC has not been installed.



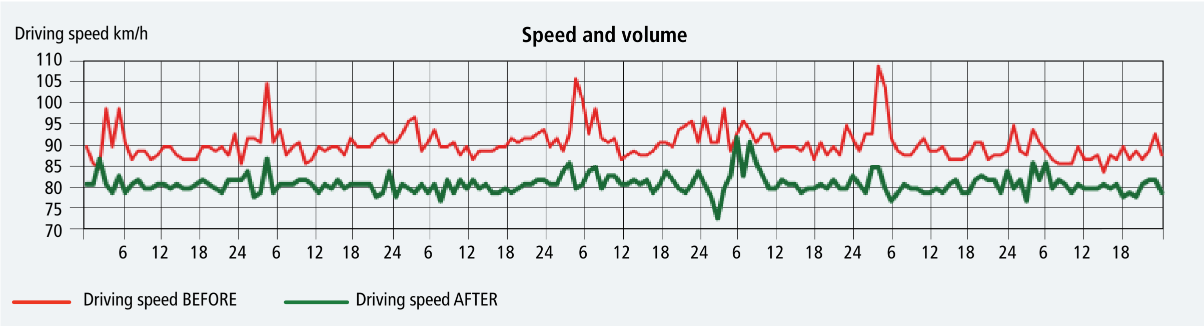
Direction 1	BEFORE	AFTER 10 weeks	AFTER 25 weeks	Change measured 10 weeks after	Change measured 25 weeks after
Average speed km/h	76.7	74,0	73.6	-2.8	-3.1
Percentage over 80	36.8	22.3	23.0		
Percentage over 90	4.1	1.4	1.4		
Volume of vehicles	11947	8025	6895		

Figure 5.2 Before-and-after study of ASSC in Bamble, hour by hour. Driving speed in km/h on representative section before and 10 and 25 weeks after the installation of ASSC. Calculated changes.

Figure 5.2 shows the same results illustrated as hourly values. Except for some night-time hours when the traffic volumes are relatively small, the figure shows that the driving speed has been reduced after the establishment of ASSC for all the hours illustrated in the figure. The percentage of motorists who drive faster than 90 km/h declined from 4.1% before ASSC to 1.4% after the system has been established. The percentage of motorists who drive faster than 80 km/h (which is the speed limit) declined correspondingly from 36.8% to 23.0%. There are no significant changes from 10 weeks to 25 weeks after the installation of ASSC.

5.1.2 E6, Dovreskogen

Similar results were found on the E6 at Dovreskogen. The section here is 5,059 metres long, and the speed limit is 80 km/h. The measurements were also carried out by radar here for a period of 16 weeks after establishment of the ASSC. The radar is located on a cross-section of the E6 which is around 3,700 m after point A (section 8, at km 10,630 metres). The traffic is relatively modest here and the measurements cover an entire week (25 March to 1 April before and 21 September to 28 September after installing ASSC). The results are shown in figure 5.3.



DOVRE Direction 1	BEFORE measured	AFTER measured	Change measured
Average speed km/h	89.4	80.6	-8.8
Percentage over 80	90.5	52.7	
Percentage over 90	42.3	9.4	
Volume of vehicles	8192	12320	

Figure 5.3 Before-and-after study of at Dovreskogen, hour by hour. Driving speed in km/h on the representative section for the situation before and after the installation of ASSC. Calculated changes.

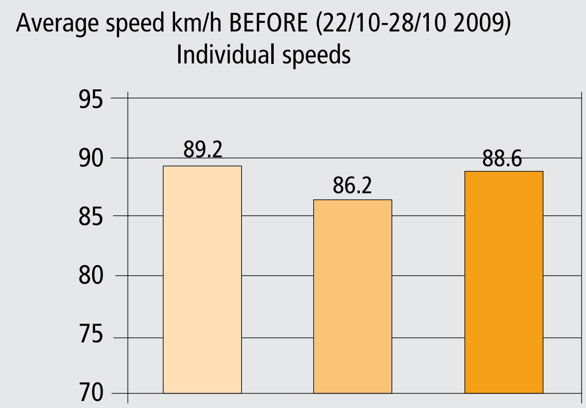
The figure shows that speed is reduced from before situation to after ASSC was established in all the 168 hours (one week) the figure covers. Overall, the speed for the entire period is reduced from 89.4 km/h to 80.6 km/h. This is a reduction of 8.8 km/h. The percentage of motorists who drive faster than the speed limit declined from 90.5% to 52.7%. The corresponding percentages that drive faster than 90 km/h are 42.3% and 9.4%, respectively.

The measurements are based on around 20,000 vehicles. As is clear from figure 5.3, there are significant differences in the volume of traffic in the situations before and after ASSC was installed. However, the volume of traffic is not high enough to contribute to a reduction in the speed level. The maximum hourly traffic in the situation after ASSC was installed is 230, compared to 160 in the situation without ASSC.

5.1.3 RV3, Langodden

In contrast to the two other sections, measuring equipment based on WIM cables was installed on the section from Barkald (point A) to Langodden (point B) on Rv3, section 14, km 1,340-10,870. In addition to a measuring point at each of the cameras, a measuring point has also been placed at Bellingmo, km 4,850, approximately in the middle of the section of road. The speed, wheelbase and weight are stored for each individual vehicle here.

Figure 5.4 shows the results from an entire week of simultaneous measurement at the three points approximately 30 weeks before the installation of ASSC. The speed limit on this section of road is 80 km/h.



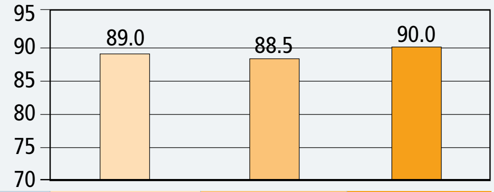
	Barkald	Bellingmo	Langodden
Number	5428	5679	5418
Average km/h	89.2	86.2	88.6
Spread km/h	9.6	10.4	10.8
Max. km/h	160.1	143.3	149.1
Min. km/h	26.9	23.9	29.3

Figure 5.4 Driving speeds (km/h) measured simultaneously at the points Barkald, Bellingmo and Langodden before the installation of ASSC at Langodden on Rv3. Spread, maximum speed and minimum speed in km/h.

The speeds at the location of the future cameras are 89.2 km/h at point A, Barkald and 88.6 km/h at point B, Langodden, respectively. The speed at the cross-section (point M, Bellingmo) is somewhat lower than the other points, 86.2 km/h. Around 5,400 vehicles are included in each of the measurement series.

By means of the wheelbase and axle weight, as well as an assumption of the travel time between two or three of the points, it is possible, using specially designed software (BILFUNN), to recognise vehicles that have passed two or three of the points (A, M or B). Through such recognition between points A, Barkald, and B, Langodden, the speed on the stretch of road prior to installation of ASSC can be calculated. The results of these calculations are shown in figure 5.5.

Speed average km/h BEFORE (22/10- 28/10 2009) 2293
Individual speeds, section and average speed

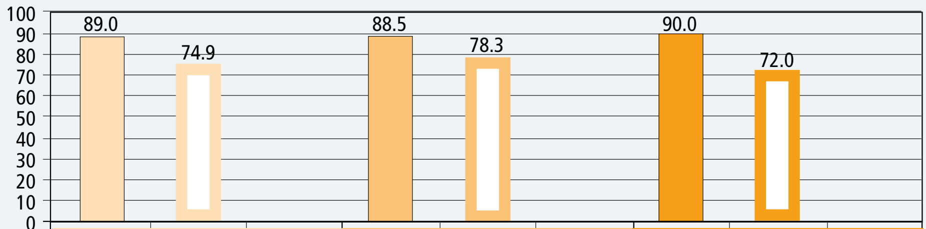


	Section speed Barkald	Average A–B speed	Section speed Langodden
Number		2293	2293
Average speed km/h	89.0	88.5	90.0
Spread km/h	7.7	7.9	5.7
Max. km/h	126	127.6	109.4
Min. km/h	62.5	50.0	69.5

Figure 5.5 Driving speeds (km/h) measured at the points Barkald and Langodden for vehicles recognised at both points. Measured average speeds from Barkald to Langodden.

Not all vehicles can be recognised in this calculation. The data basis is the same as in figure 5.4, but, as is evident from figure 5.5, around 2,300 of the 5,400 vehicles that passed have been recognised (see figure 5.4). However, the calculated speeds at Barkald (89.0 km/h) and Langodden (90 km/h) show there is no great difference between the speed of all the vehicles and the speed of the vehicles that were recognised (figures 5.4 and 5.5). The discrepancy is less than 2%. The average A–B speed can be calculated on this basis. The results comprise data from the situation before the installation of ASSC. They show that the speed is very even on this section of road, with a difference of 1.5 km/h between the measured spot speeds and the calculated average speed. When the spot speed at Bellingmo is somewhat lower than the average speed for the entire section (see figure 5.4), this means that there is some change in speed between the points.

Data from the situation after the installation of ASSC is from the operational statistics after the start-up of ASSC. This is the same type of data as from the situation before ASSC based on WIM cables, but the percentage that is recognised is significantly higher since better systems are used for the recognition of vehicles. The data comprises the results from three entire weeks of operation (same days as in the before situation, but a period of time that is three times longer). The results from the operational statistics are illustrated in figure 5.6 and compared with the data from figure 5.5. Figure 5.6 therefore illustrates the results of a complete before-and-after analysis.



	A Barkald (point)			A to B (stretch)			B Langodden (point)		
	Before	After	Difference	Before	After	Difference	Before	After	Difference
Number	2293	21873		2293	21873		2293	21873	
Average km/h	89.0	74.9	-14.1	88.5	78.3	-10.2	90.0	72.0	-18.0
Spread km/h	7.7	6.0	-1.7	7.9	6.1	-1.8	5.7	7.6	1.8
Max. km/h	126.0	112.2	-13.8	127.6	124.1	-3.5	109.4	122.8	13.4
Min. km/h	62.5	22.6	-39.9	50.0	30.4	-19.6	69.5	0.0	-69.5

Figure 5.6 Before-and-after study of ASSC on Rv3 at Langodden. Speed measured at points A and B, and average A–B speeds in km/h.

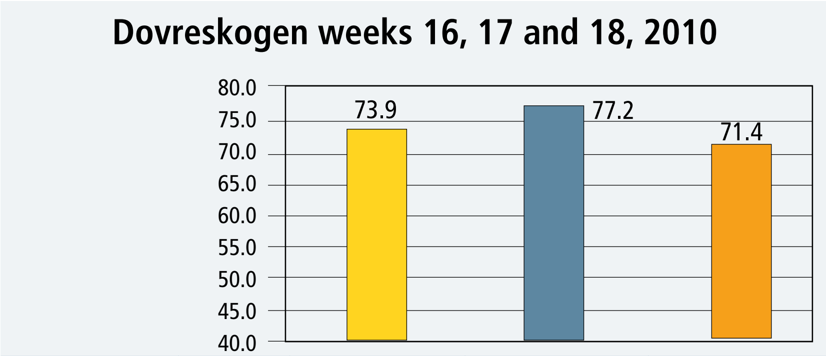
The figure is based on data from 2,293 vehicles prior to installation and 21,873 vehicles after the installation of ASSC. As can be seen, the average speed on the section is reduced by 10.2 km/h, from 88.5 km/h to 78.3 km/h after the installation of ASSC. The reduction at the points A and B is greater than for the section of road as a whole. At point A the reduction is 14.1 km/h, from 89.0 km/h to 74.9 km/h. The greatest reduction (18.0 km/h) is at point B, from 90 km/h to 72.0 km/h.

The spread in the measured driving speeds is reduced when the speed is reduced. This applies to both point A and the calculated average speeds. At point B, where the reduction in speed was the greatest, there is a tendency towards an increased spread. However, the change is not great.

5.2 Operational statistics from the period after installing ASSC

5.2.1 Motorists recognised at two points versus the average speed

As can be seen in figure 5.6, there is a tendency with ASSC for the average speed to be somewhat higher than the speed at each of the points A and B. The operational statistics that are available for all three sections can be used to investigate this further. Figure 5.7 illustrates three weeks (19 April to 10 May 2010) of continuous operational statistics from Dovreskogen on the E6. The measurements are based on almost 25,000 vehicles around six months after the start-up of the ASSC system.



N= 24942		A	A-B	B
Average speed	km/h	73.9	77.2	71.4
Spread	km/h	6.1	5.8	7.3
Max.	km/h	149.8	136.7	126.4
Min.	km/h	25.8	36.3	19.3
>80 km/h	%	11.3	22.3	6.9
>85 km/h	%	1.8	6.0	1.4
>90 km/h	%	0.3	1.8	0.4

Figure 5.7 Operational statistics, Dovreskogen. Driving speed (km/h) at points A and B, as well as the calculated average A–B speed.

The trend from Rv3 is confirmed in figure 5.7. The driving speed on this section of road is somewhat higher (77.2 km/h) than at points A (73.9 km/h) and B (71.4 km/h). The average speed is 4.5 km/h higher on the section of road than the arithmetic mean of the speed at the points. The corresponding number using the data from Barkald to Langodden (illustrated in figure 5.6) is 4.8 km/h. The percentage with a driving speed above 80 km/h, 85 km/h and 90 km/h is always greater on the section of road than at each of the points. It should also be noted that the speed at A is higher than at B. This also applies to both figures.s.

Location and period	A km/h	A–B km/h	B km/h	A–B – (A+B)/2 km/h	Number of vehicles N=
Bakkevann E18	73.7	76.3	70.8	4.0	18435
Dovreskogen E6 short	73.7	76.6	71.6	3.9	8733
Dovreskogen E6 long	73.9	77.2	71.4	4.5	24942
Langodden RV3 short	74.9	78.3	72.0	4.8	21873
Langodden RV 3 long	75.0	78.1	72.3	4.4	16368

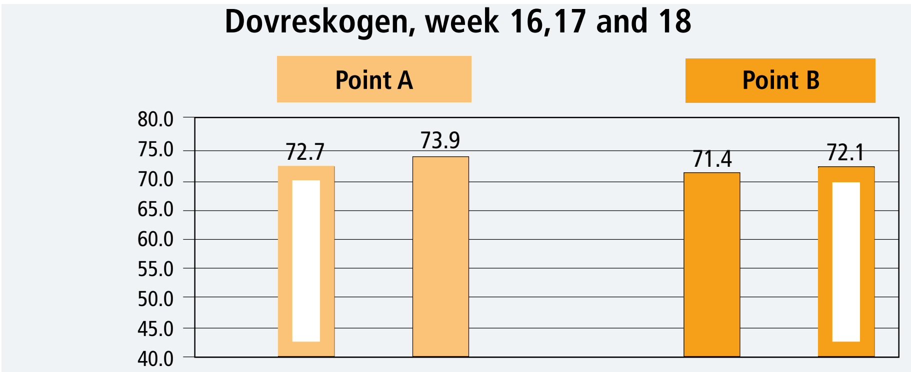
Table 5.1 Measured driving speed (km/h) at points A and B, calculated average A-B speed and the difference between the arithmetic mean (A+B)/2 and average A–B speed. The designations short and long used in the table refer to a short and long period of time, respectively, after the installation of ASSC.

Table 5.1 contains a summary of operational statistics from several sites and time periods. The table shows the driving speed at each of the points A and B, as well as the average A–B speed, all in km/h. The second to last column in the table shows the difference between the calculated average A–B speed and the arithmetic mean of the speed at points A and B.

The pattern from figure 5.7 is confirmed in all the measurements, which are based on around 90,000 vehicles in total. The average A–B speed is 4–5 km/h higher than at the speed each of the points. Further, the speed at point A is 2-3 km higher than the speed at point B.

5.2.2 Motorists registered at one point versus those who are recognised at both points

A requirement of the Data Protection Agency and the police is that no sanctions shall be imposed on the motorists' speed when passing the cameras at sites where it is possible to perform average measurements. **In principle** this makes it possible for a motorist that does not exceed the speed limit on the A–B section of road to pass (and be photographed) at the cameras at any speed without incurring a criminal sanction. Alternatively, the motorist can pass a camera at high speed, stop, turn around or adapt in some other way so that the average speed for the section of road is not too high.



N=38039		A Only	A Both		B Both	B Only
Average speed	km/h	72.7	73.9		71.4	72.1
Spread	km/h	8.6	6.1		7.3	8.7
Max.	km/h	158.0	149.8		126.4	132.2
Min.	km/h	29.0	25.8		19.3	23.0
>80 km/h	%	13.2	11.3		6.9	11.3
>85 km/h	%	2.4	1.8		1.4	2.9
>90 km/h	%	0.5	0.3		0.4	0.9

Figure 5.8 Operational statistics, Dovreskogen. Driving speed (km/h) at the points A and B. Broken down according to whether the motorists are registered at one or two points.

Figure 5.8 is based on the data that was used in figure 5.7. In addition, figure 5.8 also contains data for the motorists that are not recognised at both cameras. The column and figures labelled "A Both", with a driving speed of 73.9 km/h, indicate the speed at point A for motorists recognised at both cameras. This result is identical to A in figure 5.7. The column labelled "A Only" with, a driving speed of 72.7 km/h, represents the driving speed at point A for motorists that are registered at point A and not found at point B. "B Both" and "B Only" are to be interpreted correspondingly. The motorists "A Only" and "B Only" are thus not included in the calculations of the average A–B speed.

Figure 5.8 shows that motorists who are registered at only one camera ("A Only" or "B Only") do not have a significantly higher or lower speed than the motorists that are recognised by both cameras. At point A the average speed is 1.2 km/h higher for those who are recognised at both points than for those who were just registered at point A ("A Both" drive 1.2 km/h faster than "A Only"). At point B the opposite is true; the average speed for those who are recognised at both points is 0.7 km/h lower than those that are only registered at point B ("B Both" drive 0.7 km/h slower than "B Only"). The figure shows that the spread of the driving speed increases somewhat for the groups that are only recognised at one of the points. At point A the spread increases from 6.1 km/h to 8.6 km/h. At point B the corresponding increase is from 7.3 km/h to 8.7 km/h. Table 5.2 presents a summary from the same types of measurements as in table 5.1, but now the focus is on the **speed difference** between the two groups that are registered at one or two points as explained in figure 5.8. The values 1.2 km/h and -0.7 km/h from the measurements at Dovreskogen ("Dovreskogen E6 long") are recognised in the table.

Location and period	A Only km/h	A Both km/h	Difference A Only – A Both km/h	B Only km/h	B Both km/h	Difference B Only – B Both km/h	Number of vehicles N=
Bakkevann E18	73.9	73.7	-0.2	71.0	70.8	-0.2	28087
Dovreskogen E6 short	71.5	73.7	2.2	71.5	71.6	0.0	19831
Dovreskogen E6 long	72.7	73.9	1.2	72.1	71.4	-0.7	38039
Langodden RV3 short	74.9	74.9	0.0	73.6	72.0	-1.5	33795
Langodden RV 3 long	75.6	75.0	-0.6	72.4	72.3	-0.1	19619

Table 5.2. Difference in driving speed for those who are recognised at one and/or two points for point A and point B in km/h for different sites and periods.

The tendency from figure 5.8 is confirmed. The third column in the table shows that the difference in driving speed between those who are registered at one or both points is practically negligible. At point A the difference varies from -0.6 km/h to 2.2 km/h. At point B the difference varies from -1.5 km/h to 0. All measuring points also confirm the tendency for a slight increase in the spread of the driving speed in the group that is only registered at one point compared with those who are recognised at both.

5.2.3 Motorists' adaptation to the system

The number of motorists in Norway that drove faster than the speed limit in 2010 as registered by ASC was somewhere just under 10%. For average speed cameras this number was close to 20%. There may be several explanations for this; for example, it may be that motorists still have not quite understood how ASSC works.

In theory, a motorist who passes a ASSC section can be registered as having driven faster than the speed limit in three different ways:

1. When passing point A (first camera)
2. When passing point B (last camera)
3. When the average A–B speed is calculated

Motorists can drive faster than the speed limit in one or more of these three possible ways. However, with the use of ASSC only exceeding the average A–B speed is subject to sanctions. These two camera points and the calculated average speed give seven possible combinations of how motorists can drive faster than the speed limit. In addition, there is of course a group (group 8) that does not driver faster than the speed limit.

Table 5.3 shows the distribution of a total of 8,733 vehicles passing through the ASSC system on the E6 at Dovreskogen during the period from 9 to 19 March 2010 for the 8 groups mentioned.

Group 1 includes 363 vehicles that drove faster than the speed limit at **camera box A, and only there.**
Group 3 includes 26 vehicles that drove faster than the speed limit **at both A and B, but not on the section of road from A to B.**
Group 6 includes 268 vehicles that drove faster than the speed limit **at camera A, camera B, and on the section of road from A to B.**

A total 2,250 vehicles, or 25.8% of all (8,733) who were registered, drove faster than the speed limit.

Group no.	Speed > 80 km/h at measurement	Number of vehicles	Number of vehicles	Percentage % of all
1 2 3	A B A + B	363 123 26	512	5.9
4 5 6	A + AB B + AB A+ B+ AB	337 154 268	759	8.7
7	AB	979	979	11.2
Total 1-7 8	Speed >80km/h Speed <=80km/h	2250 6483	2250	25.8 74.2
	TOTAL all	8733		100.0

Table 5.3 Distribution of the number of motorists with a speed exceeding the speed limit by the type of measurement (point A, point B, A to B, or a combination of these), and the number of motorists below the speed limit.

The three groups (1+2+3), or a total of 512 vehicles, comprise 22.8% of all who drove faster than the speed limit or 5.9% of all who were measured. They drove faster than the speed limit at point A or B, or at both point A+B, without driving faster than the speed limit for the section of road from A to B. These motorists adapted their driving speed for ASSC so that they were not sanctioned. Groups 4+5+6 exceeded the speed limit at one or both cameras, in addition to exceeding the speed limit on the stretch from A to B. This group, which comprises 33.7% of those who drove faster than the speed limit, or 8.7% of the total, must be regarded as having very little regard at all to the measurement of their speed. The greatest percentage of those who drove faster than the speed limit are made up of the 979 (43.5% of those who drove faster than the speed limit or 11.2% of all) who did so on the section of road from A to B. This group made adaptations at each of the cameras (both A and B), but still chose a driving speed between the boxes that resulted in an average speed above the speed limit. There is reason to ask whether this group that is willing to adapt at A and B, but not A–B, has “understood” how the system works. It is possible that if these motorists were given better information, they would reduce their driving speed on the section from A to B.

5.3 Extent of speed adaptation

5.3.1 Speed adaptation after the ASSC section of road

It is crucial to the traffic safety effect of automated speed enforcement that the speed reduction that is achieved at a camera is maintained for a distance after the box has been passed. In principle this is accomplished by ASSC, since we achieve a reduction in speed for the entire section between the cameras. As previously illustrated, the reduction of the average speed is somewhat lower than the reduction at the cameras. Even though the main effect of the ASSC is achieved between the cameras and not after the last box, it is of great interest to study the motorist’s choice of speed after camera B has been passed. In part this is done in order to investigate how far the effect can be traced, but also to determine whether the speed is immediately increased to a level higher than before point A (before the entire ASSC section). Figure 5.9 shows a summary of such measurements. The number of vehicles the measurements are based on varies somewhat depending on the site, but it ranges between 10,000 and 20,000 vehicles at each site. All of them have been measured by radar.

In order to make the measurements comparable, the driving speeds measured at points after the ASC section of road are all presented as relative to the speed at box B. This is set at 100.

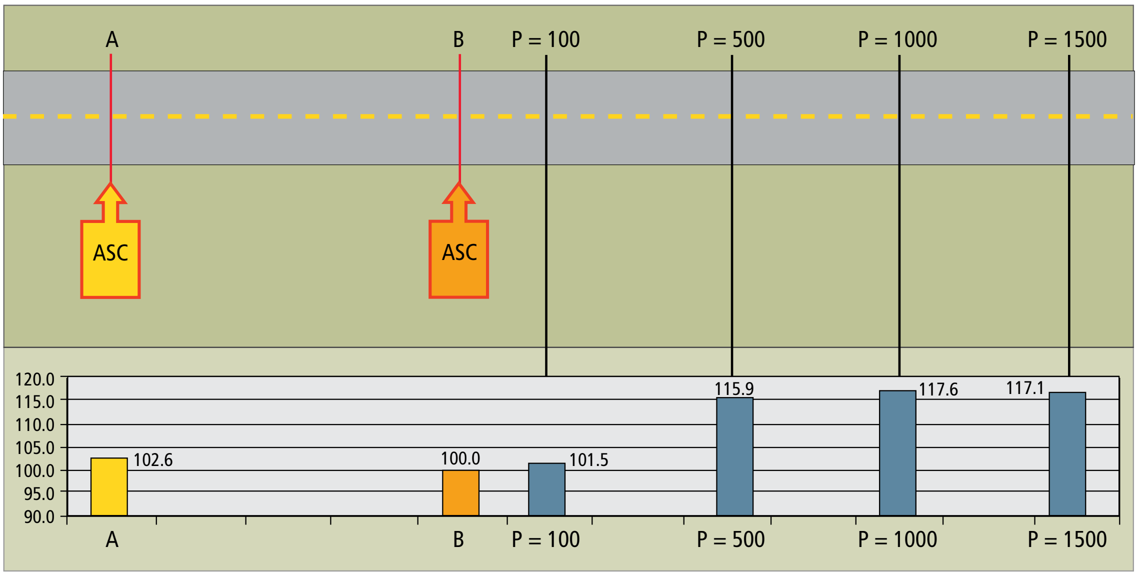


Figure 5.9 Driving speed relative to point B for points at various distances after point B. Data from Dovreskogen, E6, and Langodden, Rv3.

The figure shows the relative driving speed at the points P=100 m, P=500 m and P=1,000 m relative to the speed at point B. The point designation indicates the distance in metres from point B. When the speed at point P=500 is specified as 115.9, this means that the speed is 15.9% higher at this point than at point B. Accordingly, when the speed at point B is 71.2 km/h, the speed at point P=500 (500 metres after point B) is 82.6 km/h. By comparison, the speed at point A relative to box B is calculated as 102.6.

The results in figure 5.9 show that the speed reduction that is achieved when passing camera point B is maintained for at least 100 metres after the box has been passed. Then the speed is increased again, and after 500 metres it is 115.9 or 15.9% higher than at point B. After an additional 500 metres the speed increases further to 117.6. This level does not change until point P=1500.

5.3.2 Speed adaptation before the ASSC section of road

A speed reduction before the ASSC section of road refers here to the speed reduction before the vehicle reaches point A. This is illustrated in Figure 5.10.

The presentation and notation used are identical to the previous figure. Point P=-160 indicates a distance of 160 metres before point A. P=-1300 ditto. Point P=M indicates a point within the section of road approximately midway between A and B. The speeds are illustrated here relative to the speed at point A.

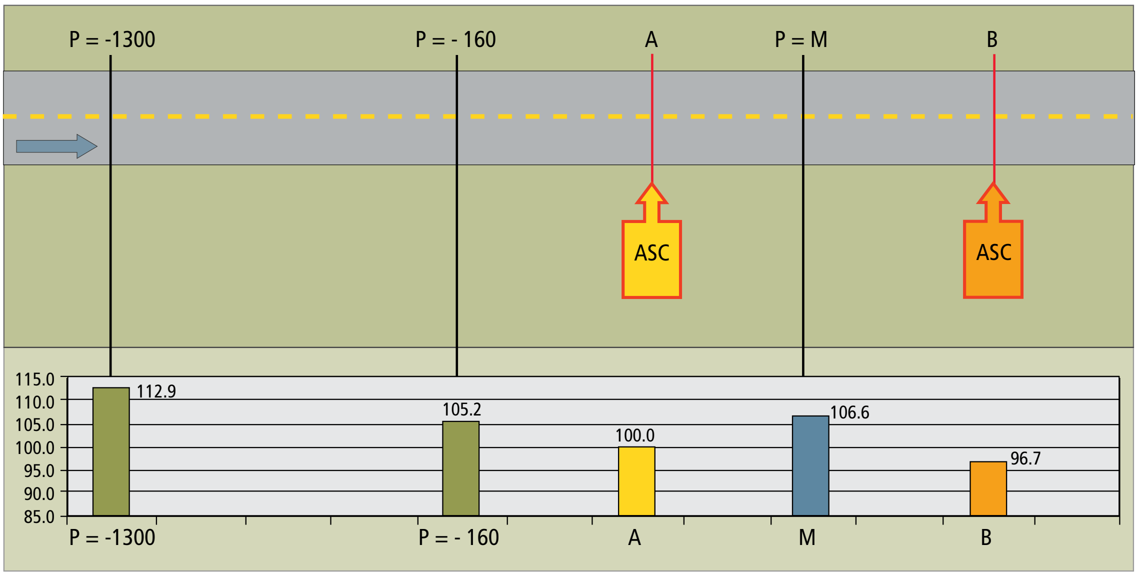


Figure 5.10 Driving speed relative to point A for points at various distances before point A. Data from Dovreskogen, E6, and Langodden, Rv3.

As is shown, the speed at point P=-160 relative to point A is 105.2, or 5.2% higher than at point A. This means that a speed reduction occurs during the last 160 metres to the camera. In practice, the speed reduction amounts to around 2 km/h. At a distance of 1,300 metres before point A, the speed is 112.9, or around 13% higher than at point A. On the E6 at Dovreskogen the corresponding speed is 84.7/h..

5.3.3 Speed adaptations 20-30 km from the ASSC sections

It is of interest how the speed level has changed at points approx. 20-30 km from the ASSC sections of road at Dovreskogen and Langodden after the introduction of ASSC. The NPRA's automatic measuring points (level 1) are used to investigate this.

The following periods have been used:

- 1– 30 June 2006 (before ASSC)
- 1– 30 June 2008 (before ASSC)
- 1– 30 June 2009 (before ASSC)
- 1– 30 June 2010 (after installing ASSC)

There is nothing to indicate that the establishment of the ASSCsections has affected the speed level of those who have driven pas at a distance from the section of road in question here. The speed level at a point that lies before or after the ASSC stretch on the E6 at Dovreskogen has not changed significantly overall since the installation of ASSC. During the period from 2007 to 2009 there was a general decline in the speed level at the points before and after the ASSC section of Rv3 at Alvdal. This applies both to those who have driven along the ASSC section of road and those who are approaching this section.

5.4 Speed adaptation at the cameras

With conventional ASC, braking just before the camera and subsequent acceleration can be a problem. When traffic is heavy and/or drivers are following other vehicles at close distances, this could increase the probability of rear-end collisions. Such braking may be due to the fact that the motorist became aware of the camera too late. This is often the case for motorists with automated speed enforcement warning devices. Speed measurement and the associated sanctions for an offence take place at the camera. This type of behaviour should be unnecessary with ASSC. Any sanctions related to average speed cameras are linked to excessive driving speed on the section as a whole between the measuring points A and B, and only there. As these points can thus be passed at an excessive speed without any sanction being imposed, braking near the camera should be unnecessary. As an initial approach to this problem, a simple registration of vehicles braking before camera A has been carried out. Measurements using a laser speed gun at point A have also been carried out on an trial basis.

5.4.1 Brake lights coming on at point A

At Langodden we have performed a simple count of the number of motorists who use their brakes in the immediate vicinity of the camera (approx. 50 metres). This is a somewhat inaccurate method, but we assumed that the brake lights indicate that the motorist wants to adjust his driving speed to a greater or lesser extent. The results of this count are illustrated in figure 5.11.

Brake light count using ASSC, Østerdalen Rv 3 at Langodden, 25–26 August 2010.

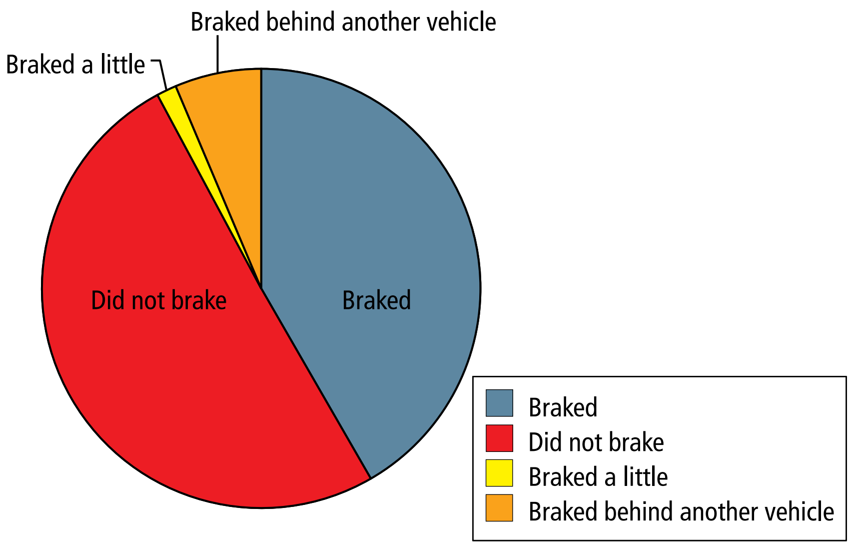


Figure 5.11 Registration of brake use at Langodden, Rv3.

The count comprises a total of 612 vehicles on 25–26 August 2010. As is shown, around 50% of the motorists chose to brake to some extent, as indicated by their brake lights coming on.

5.4.2 Speed measurement using a laser speed gun

In order to investigate motorists' behaviour near the cameras more closely, limited measurement using a laser speed gun has been carried out. The purpose was to investigate whether sudden braking occurs and whether there was thus a risk of rear-end collisions.

The measurements have not been taken for any specific section of road, but by taking as many "shots" as possible on a stretch of around 150 m on either side of the camera. However, for some vehicles, the stretch of road from the first to the last measurement is significantly less than 300 m. Vehicles with less than five registered speeds or that have only been measured on one side of the camera location have been omitted from the data. The measurements include 341 vehicles and have been carried out on a stretch of road at Langodden on Rv3.

Four typical speed profiles have been defined based on the speeds measured in different sections. These profiles are defined in Table 5.4.

Speed profile type	Description	Mathematical prerequisites
Type 1	Almost unchanged speed on approach to the camera, no speed adjustment required after passing	$V_{Section\ 1} - V_{Last\ before\ camera} \leq 2$ km/h
Type 2	Speed reduction on approach to the camera, unchanged or reduced speed after passing	$V_{Section\ 1} - V_{Last\ before\ camera} > 2$ km/h and $V_{Last\ section} - V_{First\ after\ camera\ box} \leq 2$ km/t
Type 3	Speed increase on approach to the camera, no speed adjustment required after passing	$V_{Section\ 1} - V_{Last\ before\ camera} < 2$ km/t
Type 4	Speed reduction on approach to the camera, speed increase after passing (”kangaroo driving”)	$V_{Section\ 1} - V_{Last\ before\ camera} > 2$ km/h and $V_{Last\ section} - V_{First\ after\ camera} > 2$ km/t

Table 5.4 Categorisation of four types of speed profiles based on the speed in different sections in relation to the camera box.

The classification in the table is based on the position of the various measuring sections in relation to the camera.

- Section 1 = the measuring cross-section that is located the furthest away from the camera when the vehicle is approaching
- Last before camera = the cross-section that is the closest to the camera before passing it
- First after camera box = the cross-section closest to the camera after passing it, and
- Last section = the last measured cross-section, i.e. the section furthest away from the camera after passing it

As is evident from these definitions, it is speed profile type 4 in particular that may be unfortunate. This is what we refer to as kangaroo driving.

Table 5.5 shows the distribution of the 341 vehicles among the four defined speed profile types.

Speed profile type	Number of vehicles	Percent-age
Speed profile type 1: Almost unchanged speed on approach to the camera, no speed adjustment required after passing	210	61.6
Speed profile type 2: Speed reduction on approach to the camera, unchanged or reduced speed after passing	42	12.3
Speed profile type 3: Speed increase on approach to the camera, no speed adjustmentafter passing	65	19.1
Speed profile type 4: Speed reduction on approach to the camera, speed increase after passing (”kangaroo driving”)	24	7.0
Total number of vehicles measured	341	100.0

Table 5.5 Vehicle distribution for the different speed profile types. Number and percentage

As table 5.5 shows, 24 of the 341 vehicles, or 7%, belong in the speed profile type 4 category. These are motorists who reduce their speed on approach to the camera and then increase their speed as soon as they have passed the cameras. The limit values for classification in this group are a 4 km/h change (2 km/h retardation and 2 km/h acceleration).

Further analysis of these speed profiles is illustrated in figure 5.12, where they are shown together with a trend line.

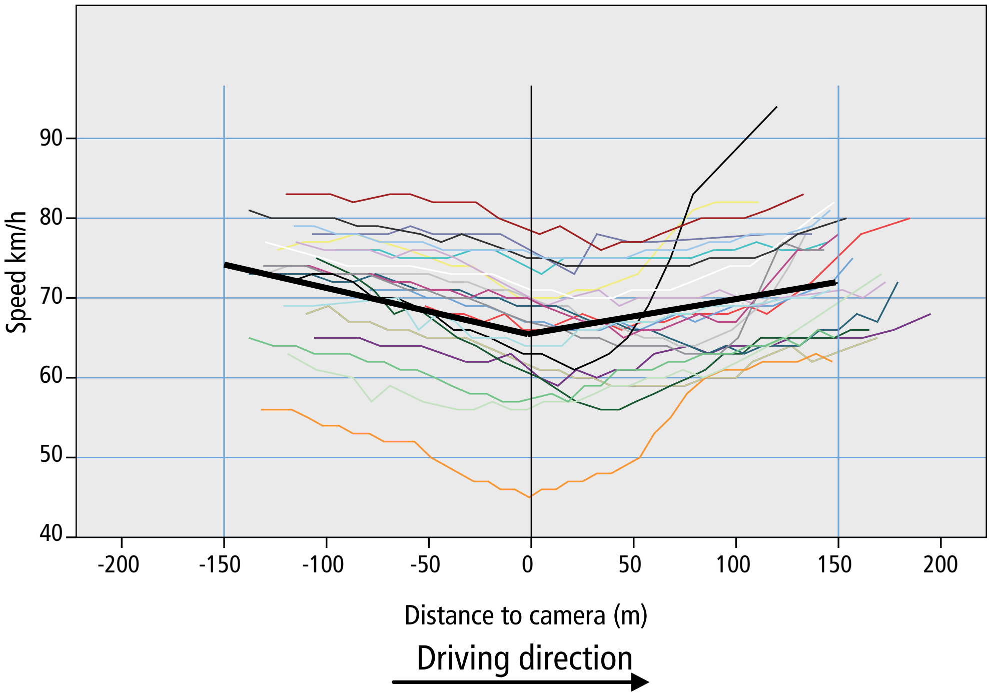


Figure 5.12 Speed profile type 4. Individual vehicles and trend line.

Figure 5.12 shows that the change in speed for 150 metres on each side of the camera is relatively modest and that there are very few vehicles that have rapid retardation combined with rapid acceleration.

6. Expected effect of ASC and ASSC on accidents, a calculation example

6.1 Relationship between a change in speed and changes in the accident rate and degree of injury

A before-and-after-analysis of the effect of measures on accidents requires follow-up and measurement over many years. Accidents should be registered over a period of at least three to four years. Calculating the expected change in the number of accidents and injuries based on the so-called ”power model” may be a preliminary alternative to such a procedure (Elvik, 2009). This is a well-recognised model that documents the relationship between the changes in driving speed and changes in the number of accidents and injuries by means of meta-analysis of a number of studies. This model can be used to calculate the expected traffic safety effect of all types of measures where the working mechanism is related to changes in the driving speed.

Figure 6.1 shows the power model in its general form.

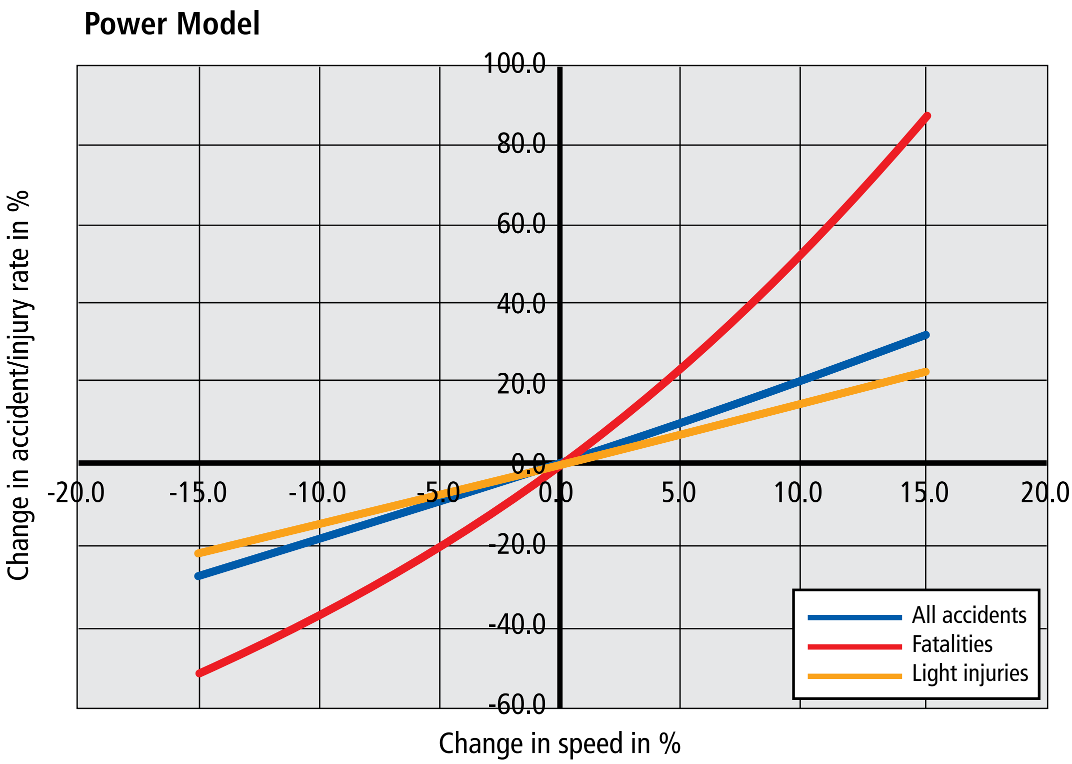


Figure 6.1 Relationship between a change in the driving speed and changes in the accident rate and injuries. Power Model (ref.).

The model shows how a percentage change in speed results in a percentage change in the accident rate and injuries. The figure shows, for example, that a 10% reduction in driving speed results in a 20% reduction in the number of accidents and a reduction in the number of deaths by up to 40%.

6.2 Calculated changes in injury and accident rates

In order to perform the desired calculations, we must use the results of the speed measurements from Langodden, Rv3, as an example, since this is where we have the best documented measurements. See the results in figure 5.6.

Figure 6.2 illustrates the automated speed enforcement system we will use for calculating the effect on injuries and accidents.

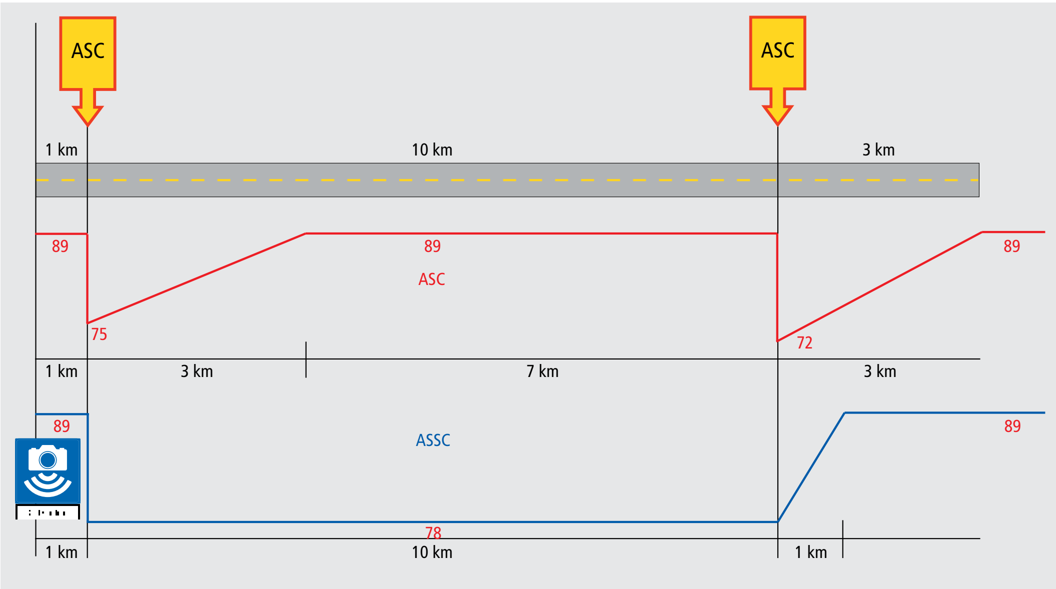


Figure 6.2: Speed profile for an alternative design of automated speed enforcement. ASC and ASSC. Length of the horizontal axis in km, driving speed on the vertical axis in km/h.

The upper portion of the figure illustrates the actual ASSC installation. The total length of the stretch of road is 14 km, and the distance from the start of this stretch of road to the first ASSC camera is 1 km. The distance between the cameras is 10 km, and we are calculating the effect on a section of road up to a point 3 km after passing camera B. The middle portion of the figure (the red curve) shows a speed profile for this installation if it had functioned as ASC with two individual cameras at A and B. The lower portion of the figure shows a corresponding speed profile for ASSC between the points A and B.

We make the following assumptions with regard to speed:

- Without automated speed enforcement:
  The speed before introducing automated speed enforcement is measured at 89.0 km/h. We use this for the entire 14 km stretch of road.

- As spot speed cameras:
  On the stretch of road before box A the speed before ASC is used, i.e. 89.0 km/h. The speed at point A is measured at 75 km/h after ASC has been installed. For ASC we presume that this effect will last for 3 km. The speed gradually returns to 89.0 km/h. The speed at point B is measured at 72 km/h after the installation of automated speed enforcement. For ASC we presume that this effect will last for 3 km.

- As ASSC:
  The speed for the section of road between the camera boxes has been measured after the installation of ASSC. We assume that this applies for the entire section of road between points A and B, but that the effect is reduced 1 km after passing point B, where the speed returns to 89.0 km/h.

With these prerequisites a calculation has been made that illustrates the difference in the effect on injuries and accidents by using the two cameras as ASC versus ASSC. The table illustrates the average effect on the driving speed on the section of road for the two types of speed enforcement and the corresponding reduction in the number of accidents and injuries of varying severity.

		Without ATC	ASC	ASSC
Average speed	km/h	89	85.7	80.8
Reduction	km/h		3.3	8.3
	%		3.7	9.2
Percentage	FA		-15.6	-35.3
Change in	VSI		-10.7	-25.2
Number	SI		-10.7	-25.2
	LI		-5.5	-13.5
	Accidents		-9.7	-23.0
	Injury costs		-14.3	-32.5

Table 6.1: Calculated effect of ASC and ASSc on driving speed (km/h and %), as well as on injuries and accidents (%). FA=Fatality, VSI=Very serious injury, SI=Serious injury, LI=Light injury

If the camera boxes were not connected, but functioned as spot speed cameras under the given prerequisites, the number of injuries would be reduced by 9.7% compared with not doing anyt-hing. The number of fatalities would be reduced by 15.6% and the number of serious injuries would be reduced by 10.7%. The calculated speed reduction for the section of road would be 3.7%, or 3. 3 km/h.

The corresponding figures for ASSC would be significantly higher. A speed reduction of 9.2%, corresponding to 8.3 km/h, would entail an expected reduction in the number of fatalities by 35.5%, serious injuries by 25.2% and light injuries by 13.5%. The expected accident rate reduction would be 23.0%. Based on the average calculated injury costs in Norway per year, a 14.3% reduction in these costs would be expected with ASC, while the corresponding figure with the use of ASSC would be 32.5%. The accident and injury costs could be even higher than this in a specific case, and thus the reduction achieved could be even greater than illustrated in this example.

7. Operational experience

7.1 Technology

Technically, there is very little difference between an installation with ASSC and an ordinary installation with ASC. The two cameras used for ASSC are equipped more or less the same as modern ASC. The aforementioned flash (section 2.2.1) was developed with average speed cameras in mind, but it is used just as much in ASC. What is unique for ASSC and had to be developed, apart from the existing system that is used in ASC, was related entirely to software. We required methods for the recognition of vehicles, systems for handling personal data, systems for processing photos from ASSC, etc. A great deal of emphasis was placed on the quality assurance of data and measuring methods. In cooperation with the Weights and Measures Authority, we now have a system where the decisive variables for speed measurement, such as the passing time and distance between points A and B, are traceable to the Weights and Measures Authority's reference values. The Weights and Measures Authority monitors our time servers that are responsible for the correct time at all times, and they have approved the measuring method used for measuring the length of stretches. In addition, the Weights and Measures Authority is responsible for periodic checks of the equipment that collects data on the vehicles as they pass the ASSC installations.

The system was thoroughly tested and developed as part of the Road Safety Lillehammer project, and when ASSC was introduced in 2009, the system functioned without any significant operational problems. There was some vandalism when the system started up in Telemark, but we have not experienced anything similar afterwards, neither there nor on any other section of road.

The installation costs for ASSC are about the same as for two ordinary ASC installations. The only difference between the two systems is minor changes in the camera box software.

In our day-to-day operations we receive feedback from the police. They are satisfied that they have two photos as a basis for an ASC enforcement, since they have a greater chance of finding at least one good photo of the driver. In addition, we have received feedback that the quality of the photos is generally good with ASSC. This is because the camera and flash are of the newest type.

Technically ASSC functions well, and we experience few operational problems.

7.2 Statistics

This section presents figures from the operations reports for the installations using ASSC and attempts to provide a picture of the traffic here in relation to the installations using traditional ASC.

It is important to point out that the figures presented here have been collected during periods when the installations have been actively monitoring traffic. This means that the "number of vehicles monitored" by an ASC installation indicates the number of vehicles that have passed during a period when the installation has been actively monitoring traffic.

The percentage of vehicles that drive faster than the speed limit is very different for ASSC than for ASC. This figure specifies the percentage of vehicles passing at a speed exceeding the speed limit while the installation is actively monitoring their speed. The percentage is illustrated in table 7.1 for weeks 1-34, 2010.

Using the percentage that drive faster than the speed limit, we obtain a figure that specifies how many vehicles pass before a photo is taken[1]. This figure can be used to calculate a comparable figure for how often a photo is taken (compared with the number of vehicles that have passed) at the different installations. See table 7.1.

	Percentage faster than the speed limit	Vehicles controlled per photo	Total number that passed
ASSC	15.0 %	325	1 016 588
ASC	8.7 %	673	99 812 872

Figures are from the period from week 1 to 34, 2010.

Table 7.1: Operational statistics for ASSC and ASC

The table shows that around 9% of the motorists maintain a speed higher than the speed limit with ASC cameras in Norway. The corresponding figure for ASSC is around 15%. This means that a photo is taken around twice as often in the installations with ASSC as in installations with ASC.

The percentage who drive faster than the speed limit with ASSC is the level we experienced with ASC a few years ago. For ASC the trend has been declining in recent years.

Since the percentage that drive faster than the speed limit is specified for the periods when the installations have been actively monitoring speed, this figure can be viewed as an indicator of the installation's potential if the surveillance periods were increased.

*) A photo here is synonymous with a photo of a vehicle that has driven faster than the speed limit. A photo in ASC is a single photo, while it is two photos in ASSC.

7.3 Privacy protection measures

In 2009 the Data Protection Agency inspected the computer system that is used for ASSC at the NPRA. The agency inspected how personal data was handled in order to ascertain whether it was stored and deleted in accordance with the regulations. The internal systems in the camera boxes and central servers were reviewed, and it was verified that all personal data in connection with a legal passing never leaves the boxes containing the cameras and is deleted as soon as the speed is determined. The same applies to personal data from illegal speeds that are older than 30 days (which is the maximum number of days that the NPRA stores personal data). The Data Protection Agency did not find any faults with the handling of personal data in connection with the current ASSC. They did, however, have some other comments/questions that are now being considered by the Privacy Protection Committee.

8. Conclusion and summary

In summarising the results from the evaluation, this section reviews and answers the questions and problems that were raised in section 2.3 (Relevant problems). For the sake of clarity, the formulated problems and the section number where they are described are included here.

- **How great is the reduction of the average speed? (2.3.1)**

This question has been answered and discussed in section 5.1 for all three sections of road. Bakkevann and Dovreskogen are the locations where the changes have been measured by means of radar. At Bakkevann the speed before ASSC was the lowest of the three locations and the reduction as a result of ASSC was therefore the lowest here. As with spot speed cameras, there is a clear correlation between the speed level before introducing automated speed enforcement and the subsequent speed reduction. At **Bakkevann on the E18,** the average hourly speed is reduced by 2.7 km/h, from 76.7 km before ASSC to 74.0 km/h ten weeks after the cameras were installed. This reduction remains stable 25 weeks after the installation. At **Dovreskogen on the E6**, the speed is reduced from 89.4 km/h to 80.6 km/h after the installation of ASSC. This is a reduction of 8.8 km/h. The percentage of motorists who drive faster than the speed limit, 80 km/h, declines from 90.5 % to 52.7%. The corresponding percentages that drive faster than 90 km/h are 42.3% and 9.4%, respectively. At **Langodden on Rv3**, where the speed was 88.5 km/h before introducing ASSC the average speed was reduced by 10.2 km/h. The reduction on this section was identified by means of a before-and-after study based on WIM cables in the road (as used in automated speed enforcement). The percentage of motorists who drive faster than the speed limit declined by the same amount as at Dovreskogen.

- **Is the speed reduction for the section as a whole as great as at each of the points? (2.3.2)**

This is illustrated in Figure 5.2.1. Here we have a clear result for all the measuring points and time periods. The speed reduction is greater at each of the camera boxes than for the stretch of road between the cameras. The greatest reduction is at point B. At Langodden on Rv3, a speed reduction of 14.1 km/h was registered for point A and 18.0 km/h for point B, while a reduction of 10.2 km/h was registered for the section of road as a whole. The conditions are similar for the other sites and time periods that were tested.

- **Do the motorists who are only registered by one camera drive faster or slower than those who are recognised at both cameras? (2.3.2)**

Since it is only the average speed that forms the basis for possible sanctions (just passing the cameras at too high a speed is not enough), it has been very important to establish that there are **no systematic differences in the driving speed** at the cameras by those who are recognised at one or both cameras. Those who are registered by one only camera do not have a significantly different driving speed than those who are recognised at both cameras. The deviations range from -1.5 km/h to 2.2 km/h. The results are based on more than 125,000 vehicle passings.

- **Do motorists drive significantly faster on a section midway between the cameras than the average speed indicates? (2.3.3)**

This result is discussed in section 5.3.2.

As the speed reduction observed at the cameras is greater than the average on the section of road as a whole, the speed measured at a point approximately in the middle of the section will be somewhat higher than the corresponding average speed. Calculated as an average from Dovreskogen on the E6, and Langodden on Rv3, the speed is 75.1 km/h at point A, 72.6 km/h at point B and 80.1 km/h at point M in the middle of the section of road. Correspondingly, the average speed for the entire section of road is 78.4 km/h. This means that the speed at a point in the middle of the section is around 2% higher than the speed for the section of road as a whole.

- **How far after the last camera is the speed reduced? (2.3.4)**

Our radar measurements after the last camera has been passed cover a distance of 1,500 metres. Here the driving speed at Dovreskogen on the E6 was measured to be 17.1% higher than when passing point B (83.4 km/h versus 71.2 km/h). We cannot rule out that the speed is influenced by the cameras, since the speed from the situation before ASSC was installed was somewhat higher than this (89.4 km/h measured by radar at one cross-section). However, the change in speed from 1,000 m after the camera to 1,500 m after the camera box is marginal. A conservative interpretation is that the speed is influenced for at least 1,000 m after point B has been passed.

- **How many motorists brake at the cameras? (2.3.5)**

Simple measurements of whether the brake lights come on show that around half of the motorists touch the brake pedal in the immediate vicinity of (around 50 m before) the camera at point A. However, laser measurements show that the degree of retardation is limited. Only 7% of the motorists slow down on approach to the cameras before accelerating again (kangaroo driving). A very small portion have a degree of retardation on approach to the camera that can represent a hazard to other motorists.

8.1 Final comments

Overall, the results are clear and positive.
ASSC appears to be an effective and strong means of achieving a significant reduction in driving speeds on sections of road where the speed is initially higher than the speed limit. The size of the reduction is dependent on the driving speed before the installation of ASSC.

Compared with conventional ASC consisting of two independent camera boxes at a distance of around 10 km from each other, calculations show that ASSC is significantly more effective, with a reduction of the driving speed and an associated reduction in injury costs that is up to three times as great.

The percentage of motorists who drive faster than the speed limit is up to twice as great for the ASSC installations we have evaluated as for conventional ASC. The results may indicate a lack of understanding of how the system works (see section 5.2.3). Informing motorists of how ASSC works may further increase the effect.

The technical operational experience with ASSC is good.

9. Future work

Having emerged as a new and powerful traffic safety measure with great effect, ASSC may be an important tool for further progress in our pursuit of Vision Zero.

The NPRA will follow this development very closely through operational statistics and supplementary studies of the effect on speed. When the installations have been operational for some time, we will also be able to follow up with studies directly related to the impact on accidents and injuries.

In parallel with the follow-up of ASSC, the NPRA will also launch further studies of ASC. There have been no detailed studies in recent years. It will be of particular interest to study the extent of the effect of ASC on driving speed after the camera has been passed.

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Appendix 1:

Differences in the measured driving speeds and the level of significance

(Kristin Sakshaug, NTNU)

To determine whether the average driving speed at a point or on a section has changed, for example, after the introduction of ASSC, statistical models are often used to calculate the level of significance. The level of significance means the likelihood that the two average values are nevertheless the same, after we have concluded that they are not, based on our calculations and criteria. A difference is said to be significant if this likelihood is less than a certain level; normally 5%. How the level of significance is calculated for the difference between two average speeds can be found at the end of this section. It can be seen there that the more vehicles the averages are based on, and the more the individual speeds are concentrated around the mean values, i.e. the lower the distribution, the less the difference between the two average speeds needs to be before it becomes significant. This is illustrated in figure V1 below. It is assumed here that we do not have any clear opinion of which of the two averages is the largest or smallest (two-sided test). If there is a hypothesis that one of the average speeds is less or greater than the other (one-sided test), as is the case before/after the installation of ASSC, the required differences will be even less than illustrated below.

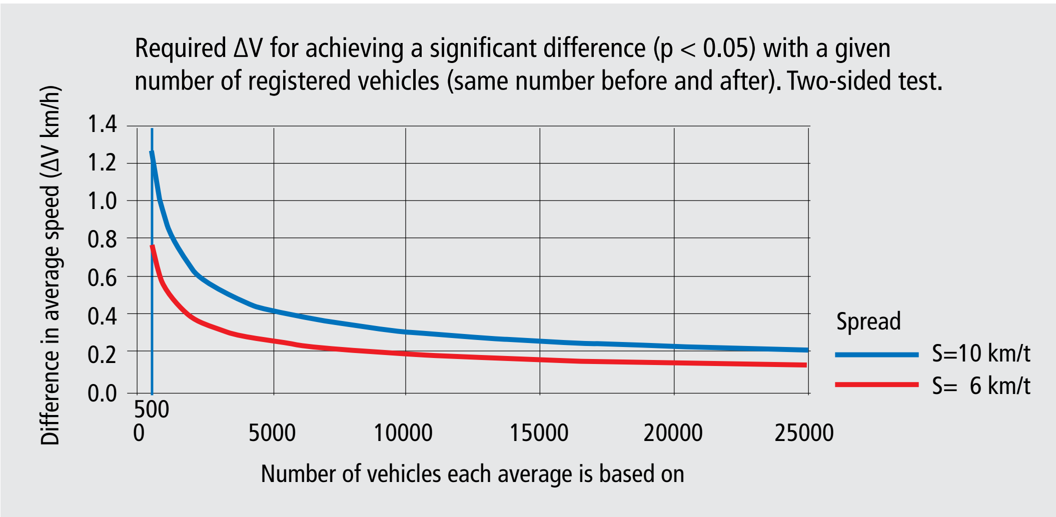

Figure V1: Required difference in the average speed in order for the difference to be significant ($p < 5\%$) as a function of the number of registered vehicles included in the average calculations (assuming the same number for both averages).

For automatic speed measurement, a large percentage of the vehicles that pass a measuring point or a section of road will be registered. This generally means that the average values are based on a relatively large number of vehicles, often several thousand. This also applies to the speed measurements that form the basis for evaluating the changes in speed before/after the installation of

ASSC in this document. This means that any changes in speed as low as 0.1-0.2 km/h will be significant. The question is, however, whether these small differences are attributed to the measure implemented (ASSC) or are due to other circumstances.

We have selected one measuring point with an AADT of around 2,000, where there have been no changes or measures in the years we are looking at. For example, we have selected week 37 and looked at the difference in the average speed between two following years. We see that all the differences are significant at the 5% level and most often by a good margin.

Table 1: Average speed in week 37 at the Snåsaheia measuring point for various years.
Level of significance for the differences between two consecutive years.

Year	Number of vehicles per week	Spread	Speed km/h
2003	12107	10.5	88.63
2004	12609	10.5	88.07
2005	12145	10.2	86.63
2006	13115	10.1	87.52
2007	13174	10.2	87.05
2008	13963	9.8	87.37
2009	13952	9.7	87.13

A

Difference between the years	ΔV	Significance level
2004-2003	-0.56	0.003 %
2005-2004	-1.44	< 0.001 %
2006-2005	0.89	< 0.001 %
2007-2006	-0.48	0.014 %
2008-2007	0.32	0.737 %
2009-2008	-0.24	3.637 %

B

Based on the above, we can see that even small differences in the average speed will be significant for the number of measured vehicles in question when evaluating the change in speed upon the installation of ASSC. However, this does not automatically mean that the installation has resulted in a significant change in the speed level. If we compare the average speed for the same week for the two subsequent years where the AADT is around 2000, it is not uncommon to find differences in the average speed of around 2 km/h during the summer. During winter the differences will often be much greater. These differences are attributed then to significant differences in the weather and road conditions from year to year, and in the composition of the traffic.

In order to attribute the change in driving speed to the safety measures implemented, the change should be greater than what would normally occur as a result of natural causes, as mentioned above. We could of course accept smaller changes if we had control over the weather, road conditions and traffic situations during the periods that have been compared.

Since ”any” difference in the average speed is significant, including differences that probably cannot be attributed to the establishment of ASSC, we have not seen any benefit from performing significance calculations.

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