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Project memo

Video-based traffic counting

Registrations for the SUSTRANS project

VERSION	**DATE**
1.0	2018-06-22

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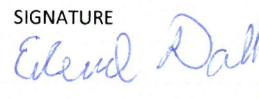|	
PROJECT NO.	**NO. OF PAGES AND APPENDICES:**
102014225	39 incl. appendices

ABSTRACT
This document describes initial results and findings from video-based traffic counting in Geiranger. An automatic video analysis system developed by SINTEF was tested and utilised to provide traffic counts for the SUSTRANS project.

13 recording units were placed in and around Geiranger to count the traffic in key areas. This memo shows where the units were placed, when they were recording, and briefly how the automatic analysis works.

Traffic counts from the automatic analysis are compared with both manual counts and NPRA counting sites. It is shown that the automatic analysis still can be much improved, but that it delivers good data provided the recording units are placed optimally.

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PROJECT MEMO NO. N-1/18	**CLASSIFICATION** Unrestricted

Document history

VERSION	DATE	VERSION DESCRIPTION
1.0	2018-06-22	Final version

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1 Background

1.1 The SUSTRANS project

Rural tourism pressure areas like Geirangerfjord, Flåm and Lofoten represent a unique challenge in transportation planning due to high seasonal fluctuations in requirements to transportation systems. These remote but honeypot areas have the combined problem of peripherality and congestion. In peak periods, traffic jams and visible local pollution are imminent problems. In a broader time-perspective, degradation of the environmental quality and scenic beauty of the areas are critical concerns. Policymakers and other stakeholders need to consider possible measures connected to sustainable transportation systems in these areas, seeing various modes of transportation in context and assessing both social, economic and environmental impacts.

SUSTRANS aims to assist decision-makers in improving transportation systems in rural tourism pressure areas, using the Geiranger World Heritage area as a case study. Through development and combination of transportation system modelling, decision analysis and stakeholder involvement, the project will explore alternative improvement measures in both the short and long term using holistic approaches. More information about the project may be found on www.sustrans.no.

The project is led by NTNU and is a collaboration with Volda University College, SINTEF Technology and Society and the University of Bonn. The project is funded by the Norwegian Research Council under the Transport 2025 program and will take place in the period 2017-2020.

1.2 Traffic counts and video analysis in SUSTRANS

A new system for counting traffic using automatic video analysis was developed and tested by SINTEF during the winter of 2016/2017. This activity was financed by SINTEF, independently of the SUSTRANS project. To gain further experience with this system and any requirements regarding the recordings to be analysed, it would be useful to run the system on a larger amount of video recordings.

During the Spring of 2017, it was decided that the SUSTRANS project (which needed traffic data from the area around Geiranger) and the video analysis project (which needed a proper test of the system) could kill two birds with one stone by testing the video analysis in Geiranger. This would provide the SUSTRANS project with traffic counts to supplement the official NPRA counts, and provide SINTEF with more practical experience with automatic video analyses. The data collection in Geiranger was partially financed by the SUSTRANS project.

2 Automated system for video analyses

This system works by analysing traffic videos frame by frame, and tracking movements throughout the video using classic techniques in the video and image analysis field, combined with artificial intelligence algorithms for identifying and classifying the moving objects (as for example car, bus or bike).

Such a system can be trained to identify all kinds of traffic, as opposed to classical traffic counting methods which are typically only able to count vehicles (inductive coils, pneumatic tubes, infrared, etc). A video system is able to count anything that moves, and if it is properly trained, it will be able to reliably count several different types of traffic, and provide other valuable information (for example size, speed, movement path).

The analysis units developed in this project also has the advantage that they are small and cheap, which makes it easy to deploy them anywhere for short periods of time.

2.1 Main system features

The analysis system can analyse video recordings completely automatic after the initial semi-automatic training. To provide a starting point for the automated routines, a human must first manually annotate a few hundred of the moving objects in the video. In the current system, this must be done once for each recording location. In a future system it should be investigated how well training from one location transfers to another recording location.

The analysis system then uses the manual annotations to train and test a wide range of classical simple artificial intelligence algorithms (KNN, CBR and ANN with different parameters) into recognising the different types of objects. In a future version of the analysis system, more modern AI algorithms should be used. The algorithms are automatically ranked from best to worst by comparing their suggested classifications with the manually annotated moving objects, and the algorithm that has the most correct classifications on the test set is used to automatically classify the moving objects in the rest of the video into the categories listed below.

Once a human has manually annotated the first few hundred objects, the rest of the analysis is fully automatic.

The traffic counts are separated into five categories:
- Pedestrian
- Bike (includes motorbike)
- Heavy vehicle (includes buses, trucks/lorries and other large vehicles)
- Camper (includes light vehicles with a caravan)
- Light vehicle (includes all vehicle types smaller than a camper)

Results from the system are stored in an SQLite database, from which they can be exported to for example CSV files, which can be opened in Excel. Such files can be formatted to suit the needs of the user, and can for example contain a timestamp, driving direction, vehicle class, size and speed.

2.2 Privacy issues and permissions

The recordings in Geiranger were reported to and approved by the Norwegian Data Protection Authority (Datatilsynet), with the following security precautions:

- Cameras will be placed at an angle where faces and number signs are hidden whenever possible.

- Cameras will be placed far enough away to prevent faces and number signs from being recognizable whenever possible.
- The resolution of the recorded videos will be low to further prevent capturing identifiable information.
- The recording units will be placed at inaccessible and/or hidden locations to prevent anybody from stealing the recorded videos.
- The controller is a Raspberry Pi v1.3, which has no wireless communication that can be exploited by a thief – physical access is thereby required to steal any data.
- The controller will be secured with a long and difficult password to make it harder for a potential thief to access the data.
- Once the recording is finished, the units will be retrieved, and the recorded videos will be stored on an encrypted hard drive with limited access until they have been processed.
- Once the videos have been processed, they will be securely deleted with multiple random overwritings.

In a future version of the video analysis system, the goal is to make the analysis run live, which removes the need for storing any videos at all. With such a system, completely anonymous counts can be stored instead, making it a much smaller privacy risk.

3 SUSTRANS video recordings

3.1 Equipment

20 prototype recording units were produced, all equipped with water proof boxes, low energy cameras, and batteries that could last for up to five days with 10 hours of recording every day.

The controller and the battery were attached to the inside of the box using velcro strips for easy maintenance. The camera was attached using putty. Since the box is mostly transparent, this made it very easy to reposition the camera to point at the road regardless of how and where the box was placed.

The controllers were slightly modified to reduce their power usage, and programmed to record only between 08:00 and 18:00. When they are not recording, the controllers will drain much less power from the battery.
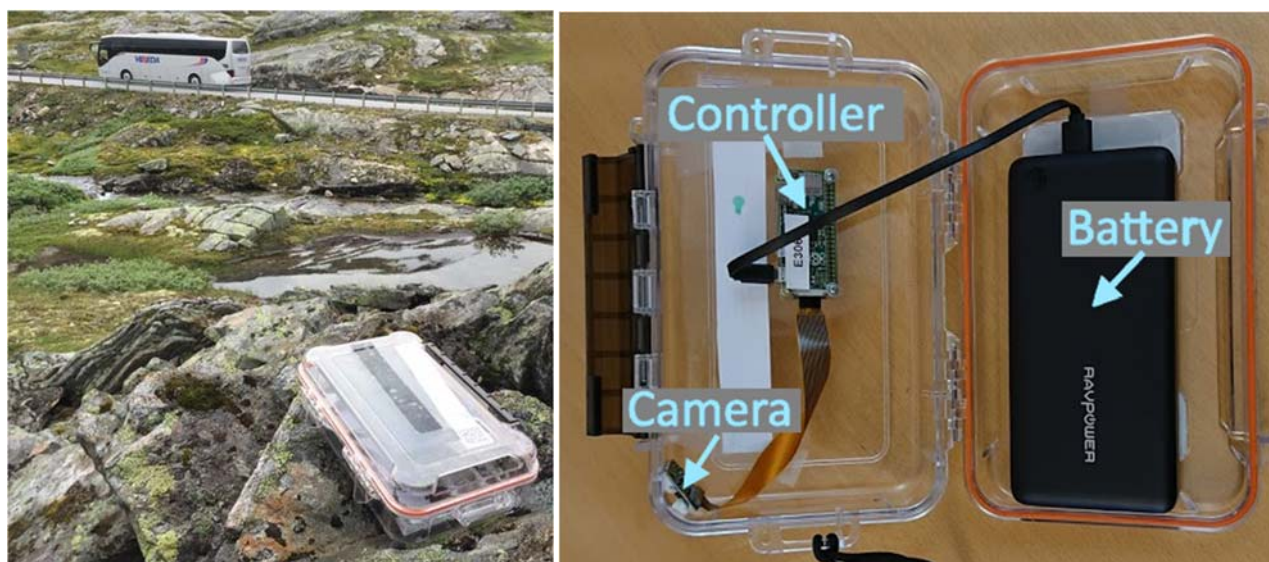

Figure 1 Left: A recording unit placed on the road side, recording a passing bus. Right: A recording unit opened to show the controller (a Raspberry Pi Zero v1.3), the camera (an RPi Camera v2) and a battery (a RavPower 26800mAh power bank).

The controller and the camera are very small, but in order to power them for five days, a large battery is required. As seen in Figure 1, most of the space inside the box is taken by the battery. For shorter periods of time, the battery (and thus the entire recording unit as well) could be made much smaller.

Some of the boxes were also equipped with a small rain shield to protect the camera's field of view from rain drops running down the outside of the box. Due to the varying camera placements, it was infeasible to equip all the boxes with rain shields. The analysis showed no difference between the recording quality of units with and without a rain shield.

All the boxes were locked with a padlock and hidden outside of view for passersby to prevent anybody from stealing the equipment.

A very early prototype of a wired communication app was developed in order to help deploy the recording units. This app was connected to the controllers using a cable, and could send a photo of the current view of the camera to the phone, to verify that the camera was pointed correctly at the road. Unfortunately, since the app required a cable for security reasons, it could only show the view before the box was closed and the

camera was properly fastened. It proved to be challenging to first aim the camera, and then fasten it without moving it at all, which resulted in some suboptimal viewing angles.

3.2 Recording locations

In total 13 recording units were deployed in and around Geiranger. Two of these units were misconfigured, and collected no data: one unit before the parking lot above Ørnesvingen (slightly south of #1), and one at Fjordbua (south of #4). The map in Figure 2 shows the 11 remaining units that gave usable data.
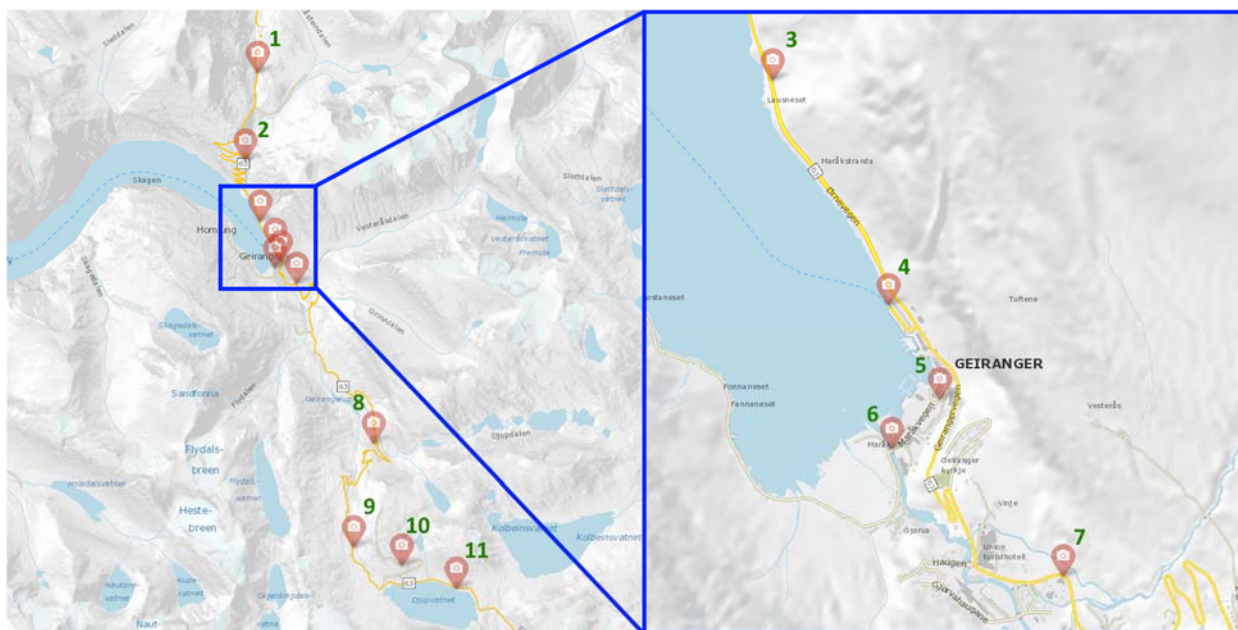

Figure 2 A map showing the 11 recording units that delivered usable data.

In addition to these, one unit was planned at Ørnesvingen (west of #2), but no suitable places for mounting the unit was found. This is also the case for a planned unit on the road stretch between the convenience store (Joker) and Geiranger Camping (between #5 and #6).

3.3 Recording period and hours

As shown in Figure 3, traffic levels at the NPRA counting site Grande has peaked around week 29-30 the previous years. Ideally, the video recording period should have been conducted in this period, in order to capture the peak traffic situation in the area. For practical reasons however, recordings could not start until early August 2017.

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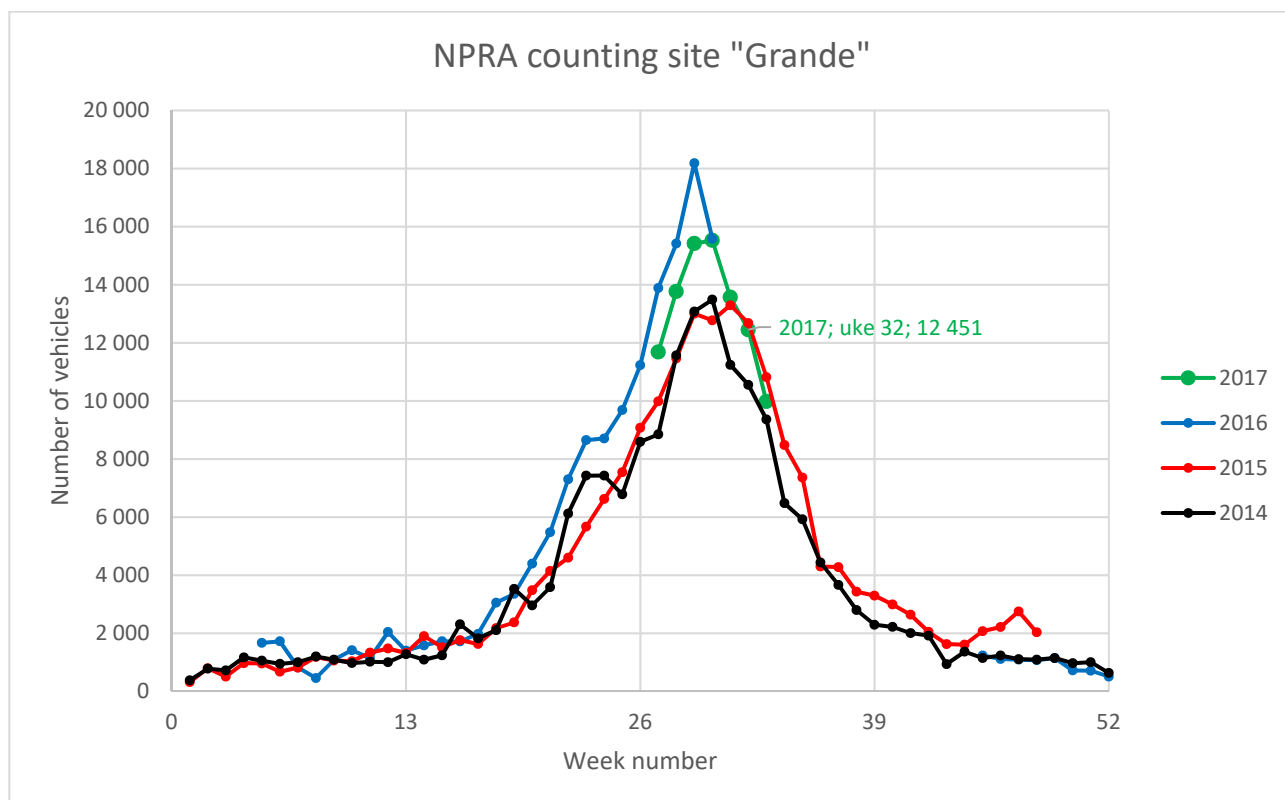
Figure 3 The number of vehicles passing the NPRA counting site "Grande" every week of the year from 2014 to 2017.

Based on the arrival dates for cruise ships to Geiranger, the dates 6th to 10th of August (week 32) were identified as most suitable for recording, as this was the five-day period with the most passengers arriving.

The recording units were deployed on Friday and Saturday the 4th and 5th of August 2017. The units were configured to record data between 0800 and 1800 from Sunday 6th of August to Thursday 10th of August.

4 Resulting recordings and data

4.1 Data overview

In total, 340 hours of video was recorded from the 11 valid units. The recordings resulted in approximately 240GB of data for further analyses. Number of hours of recording per site and day is shown in Table 1.

Table 1: Location and hours of video from the 11 valid recording units

Recording unit		Recording hours, week 32, 2017					
#	Description	Total	Su	Mo	Tu	We	Th
1	North of the parking lot above Ørnesvingen	41	1	10	10	10	10
2	Ørnevegen	1	1	0	0	0	0
3	Between the ferry quay and Fjord Hotel	41	1	10	10	10	10
4	Ferry quay	41	1	10	10	10	10
5	Geiranger Galleri	39	1	8	10	10	10
6	The bridge at Geiranger Camping	20	1	9	10	0	0
7	Gildetun	41	1	10	10	10	10
8	The bends at Kvanndalsfossen	1	1	0	0	0	0
9	North of Dalsnibba	35	1	10	10	10	4
10	The road to Dalsnibba	1	1	0	0	0	0
11	South of Dalsnibba	41	1	10	10	10	10

Because of a technical error, only a single hour of data was recorded on Sunday 6th of August. This error was repaired Sunday night/Monday morning, and most of the recording units collected data as planned the remaining four days.

Units #2, #8 and #10 had issues with their batteries, and did not collect any more data after the single hour on Sunday. The unit at Geiranger Camping ran out of battery Tuesday night, and the unit before Dalsnibba ran out about halfway through Thursday. The rest of the units recorded for the entire period.

Data from the registrations can be viewed at https://mobility.sintef.no/geirangermap/. On this web page it is possible to view hourly and aggregated data from each of the recording units. A screenshot from this web page is shown in Figure 4.

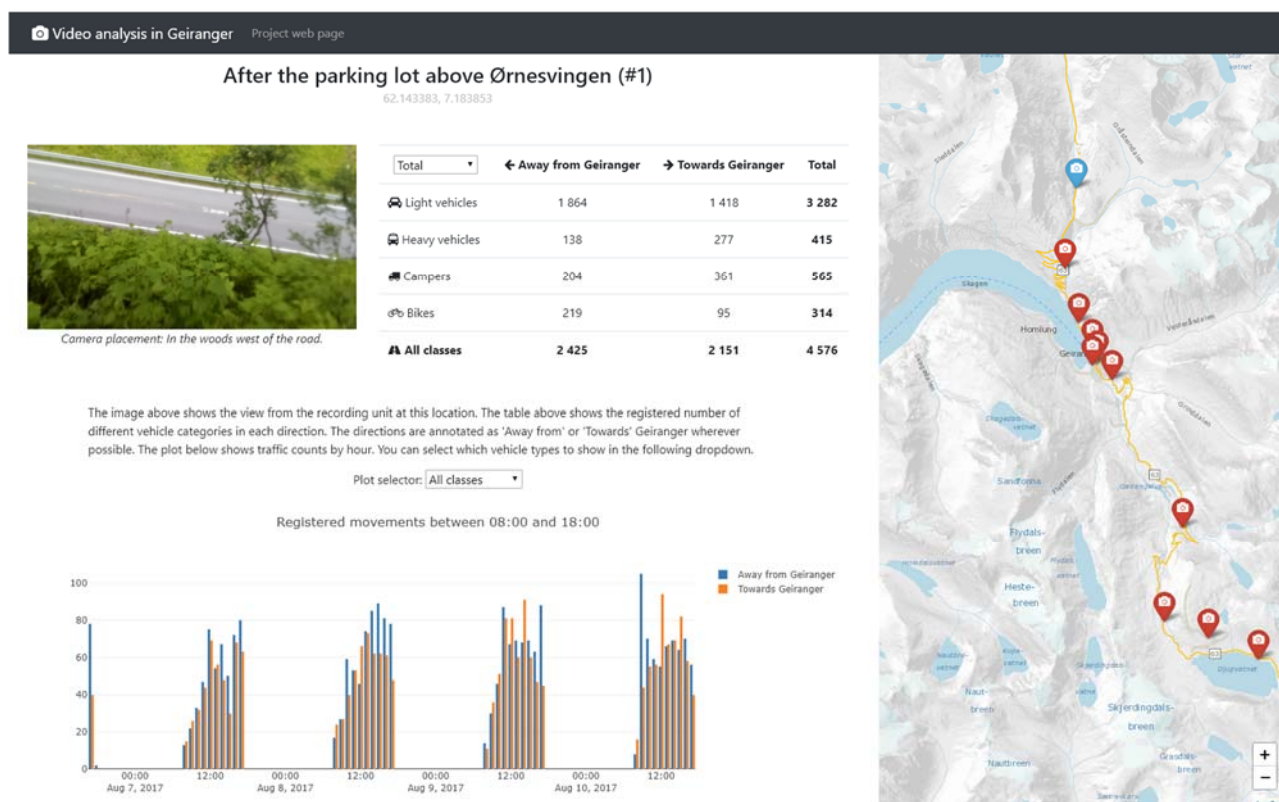Main results per recording site are presented in Appendix A.

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Figure 4 A web page that shows the results from each of the recording sites.

4.2 The individual sites - quality of recording and analyses

This section shows an image and a detailed table for each of the recording units that collected data all days. The units that only collected data for a single hour (on Sunday) are not included here, as the amount of data was so low that training the AI algorithms practically gave it the correct answers for the entire video.

For each location, a screenshot from the videos is shown. The bright area with the red border shows which part of the view was used for the analysis. This area was manually selected for each location, in order to provide the automatic system with an area of interest. A table lists the traffic counts returned by the automatic analysis (the "Analysis" column), the actual traffic counts (the "Actual" columns), and the difference between them. The actual counts for the hours shown in this section were manually counted by SINTEF. The numbers shown here is from the hour between 11:00 and 12:00 Thursday 10th of August for the units that had data from this hour, and the most similar hour for those that did not.

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4.2.1 Recording unit #1, north of the parking lot above Ørnesvingen

Large amounts of vegetation and a slightly low camera angle reduced the quality of the data in this location. The usable area was just large enough to work, but too small to reliably identify passing vehicles (especially in the upper lane, driving away from Geiranger, as seen in the table).

Figure 5 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from left to right on this image are driving towards Geiranger.

Table 2 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Towards Geiranger			Away from Geiranger			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	**Analysis**	**Actual**	**Error**
Pedestrian	0	0	0	0	0	0	0	0	**0**
Bike	2	3	-1	3	5	-2	5	8	**-3**
Heavy vehicle	16	6	10	6	7	-1	22	13	**+9**
Camper	3	5	-2	6	12	-6	9	17	**-8**
Light vehicle	35	45	-10	44	51	-7	79	96	**-17**
Total	**56**	**59**	**-3**	**59**	**75**	**-16**	**115**	**134**	**-19**

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4.2.2 Recording unit #3, between the ferry quay and Fjord Hotel

Because of the road and the surrounding terrain, this unit had to be placed far away from the road, behind a lot of vegetation. Still, the usable area was just large enough to catch all types of vehicles.

Figure 6 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from right to left on this image are driving towards Geiranger.

Table 3 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Towards Geiranger			Away from Geiranger			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	**Analysis**	**Actual**	**Error**
Pedestrian	3	3	0	3	6	-3	6	9	**-3**
Bike	5	4	+1	5	4	+1	10	8	**+2**
Heavy vehicle	12	12	0	10	10	0	22	22	**0**
Camper	10	10	0	2	10	-8	12	20	**-8**
Light vehicle	73	75	-2	72	71	+1	145	146	**-1**
Total	**103**	**104**	**-1**	**92**	**101**	**-9**	**195**	**205**	**-10**

4.2.3 Recording unit #4, ferry quay

It was very hard to find a good spot with a good angle on the ferry gangway, so the view is very poor. There is also water in the background, which gives a lot of movements that has to be filtered. This caused problems for the large vehicles, but the system was relatively precise on the number of pedestrians. There is also a lot of traffic on the road in the lower part of the image, which often blocks the view of the gangway, and disturbs the counting at this location.

Figure 7 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from left to right on this image are embarking the ferry.

Table 4 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Embarking the ferry			Disembarking the ferry			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	Analysis	Actual	Error
Pedestrian	154	174	-20	58	55	+3	212	229	**-17**
Bike	0	2	-2	0	0	0	0	2	**-2**
Heavy vehicle	18	6	+12	9	4	+5	27	10	**+17**
Camper	14	5	+9	5	0	+5	19	5	**+14**
Light vehicle	14	9	+5	8	10	-2	22	19	**+3**
Total	**200**	**196**	**+4**	**80**	**69**	**+11**	**280**	**265**	**+15**

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4.2.4 Recording unit #5, Geiranger Galleri

This unit had a good view of the road, but the viewing angle could have been better. Tourists moving in groups are very hard to count correctly, which causes a large error in the pedestrian row of the table.
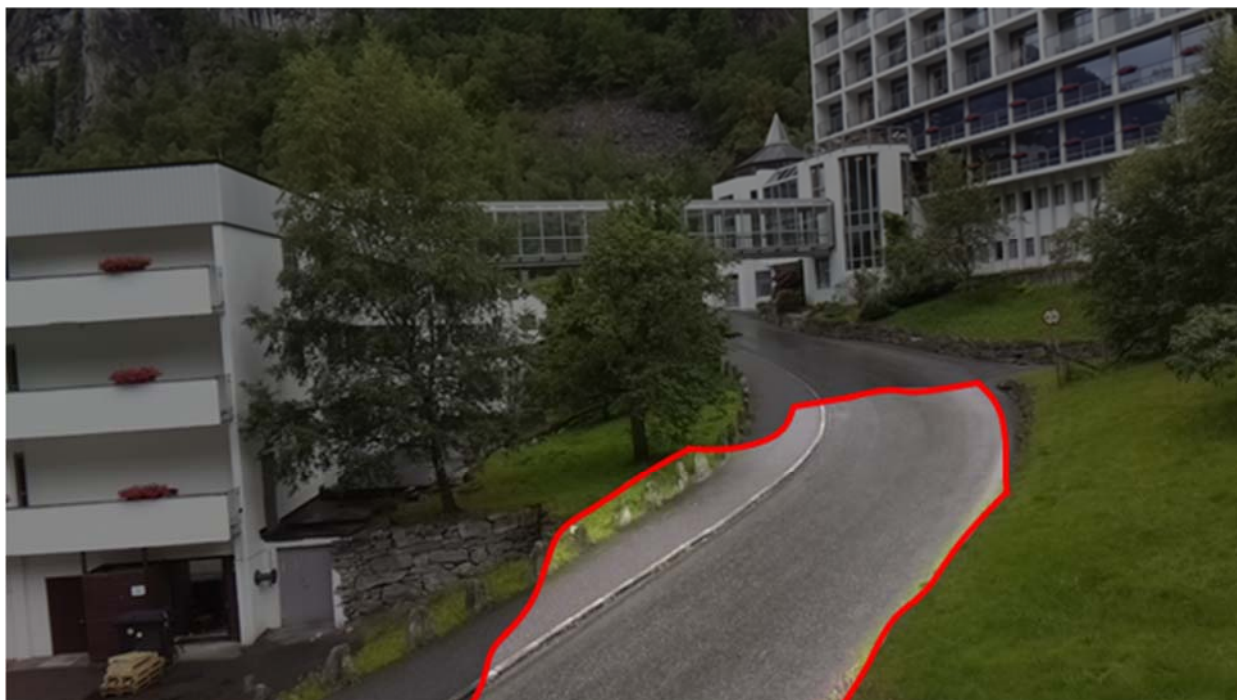

Figure 8 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from bottom to top on this image are driving away from the gallery.

Table 5 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Away from the gallery			Towards the gallery			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	Analysis	Actual	Error
Pedestrian	68	78	-10	73	94	-21	141	172	**-31**
Bike	3	4	-1	0	1	-1	3	5	**-2**
Heavy vehicle	5	5	0	7	3	+4	12	8	**+4**
Camper	21	18	+3	7	6	+1	28	24	**+4**
Light vehicle	51	52	-1	52	46	+6	103	98	**+5**
Total	**148**	**157**	**-9**	**139**	**150**	**-11**	**287**	**307**	**-20**

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4.2.5 Recording unit #6, the bridge at Geiranger Camping

At Geiranger Camping there were no good spots to mount the recording unit, and it had to be mounted on ground level. Therefore, it was often blocked by tourists watching the river, or eating lunch on the grass. There were often large amounts of tourists walking over the bridge simultaneously, so both the analysis and the manual count of pedestrians are probably a bit off.

Figure 9 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from right to left on this image are driving towards Geiranger.

Table 6 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Towards Geiranger			Away from Geiranger			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	Analysis	Actual	Error
Pedestrian	264	206	+58	613	503	+110	877	709	**+168**
Bike	0	6	-6	0	2	-2	0	8	**-8**
Heavy vehicle	0	0	0	0	0	0	0	0	**0**
Camper	10	8	+2	12	2	+10	22	10	**+12**
Light vehicle	12	15	-3	9	16	-7	21	31	**-10**
Total	**286**	**235**	**+51**	**634**	**523**	**+111**	**920**	**758**	**+162**

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4.2.6 Recording unit #7, Gildetun

This unit got a very good view on the road from the attic window at Gildetun, and gave very good results. There is some mix-ups between the light and heavy vehicle categories, which is probably caused by medium sized vehicles that are hard to reliably place in the correct category.

Figure 10 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from right to left on this image are driving towards Geiranger.

Table 7 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Towards Geiranger			Away from Geiranger			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	**Analysis**	**Actual**	**Error**
Pedestrian	12	13	-1	30	23	+7	42	36	**+6**
Bike	4	3	+1	4	4	0	8	7	**+1**
Heavy vehicle	14	14	0	18	10	+8	32	24	**+8**
Camper	5	6	-1	15	16	-1	20	22	**-2**
Light vehicle	63	64	-1	79	87	-8	142	151	**-9**
Total	**98**	**100**	**-2**	**146**	**140**	**+6**	**244**	**240**	**+4**

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4.2.7 Recording unit #9, north of Dalsnibba

This unit had a good viewing angle, but it was placed so far from the road that it was difficult to catch all the movements. Because of the distance from the road, it is hard to reliably separate the vehicle classes from each other.

Figure 11 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from left to right on this image are driving towards Geiranger.

Table 8 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Towards Geiranger			Away from Geiranger			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	Analysis	Actual	Error
Pedestrian	0	0	0	0	0	0	0	0	**0**
Bike	6	5	+1	10	9	+1	16	14	**+2**
Heavy vehicle	17	10	+7	4	3	+1	21	13	**+8**
Camper	4	4	0	12	19	-7	16	23	**-7**
Light vehicle	39	49	-10	68	79	-11	107	128	**-21**
Total	**66**	**68**	**-2**	**94**	**110**	**-16**	**160**	**178**	**-18**

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4.2.8 Recording unit #11, south of Dalsnibba

This unit was also placed far from the road, and with a poor viewing angle (not perpendicular to the road). Because of the distance and angle the system has failed to properly separate campers and buses from each other.

Figure 12 The full view (the entire image) and the recording area (the bright area inside the red border) for this recording unit.

Vehicles driving from bottom to top on this image are driving towards Geiranger.

Table 9 The results from this recording unit compared to actual counts made by watching the videos and counting manually. These numbers represent the hour from 11:00 to 12:00 Thursday 10th of August 2017.

Travel mode	Towards Geiranger			Away from Geiranger			Total		
	Analysis	Actual	Error	Analysis	Actual	Error	Analysis	Actual	Error
Pedestrian	0	0	0	0	0	0	0	0	**0**
Bike	3	5	-2	12	14	-2	15	19	**-4**
Heavy vehicle	6	5	+1	14	0	+14	20	5	**+15**
Camper	5	6	-1	10	20	-10	15	26	**-11**
Light vehicle	51	54	-3	52	57	-5	103	111	**-8**
Total	**65**	**70**	**-5**	**88**	**91**	**-3**	**153**	**161**	**-8**

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4.3 Summary of the manual validation results

Since the recording units could not be placed at the top of lamp posts, they were mounted on a lot of different places with varying recording conditions. It is now obvious that the units should be placed around 10 meters from the road, preferably high up, and with as close as 90 degrees on the traffic direction. The road segment to be recorded should be as straight as possible where the camera is positioned.

Even with the varying conditions, the system managed to catch 95% of the movements on the eight hours of video that were verified. The analysis system still has a large potential for improvement, especially when it comes to reliably classifying the movements into the movement categories.

Table 10 shows an aggregate of all the tables listed in the previous sections.

Table 10 The sum of all the observations (both from the recording unit and from the manualy counts) from the previous sections. The two rightmost columns shows the total error as both the actual number of vehicles, and as a percentage value.

Travel mode	Analysis	Actual	Total error (#)	Total error (%)
Pedestrian	1278	1155	123	+11%
Bike	57	71	-14	-20%
Heavy vehicle	156	95	61	+64%
Camper	141	147	-6	-4%
Light vehicle	722	780	-58	-7%
Total	**2354**	**2248**	**106**	**+5%**

4.4 Validation against data from NPRA counting sites

There are five NPRA counting sites in the Geiranger area, three of which are counting the same road stretches as one of the SINTEF recording units:

- NPRA sites "Grande" and "Geiranger" are located on the same road as SINTEF recording unit #3
- NPRA site "Djupvasshytta" is located on the same road as SINTEF recording unit #11.
- NPRA sites Resmyrane and Flydalen are located too far away from the SINTEF recording units to be of use.

Unfortunately, the NPRA site "Djupvasshytta" did not deliver data for the recording period. Therefore, the only direct comparison is between the "Grande" and "Geiranger" sites and SINTEF recording unit #3.

As shown on the map in Figure 13, those are all located on the same road stretch, but not in the exact same locations.

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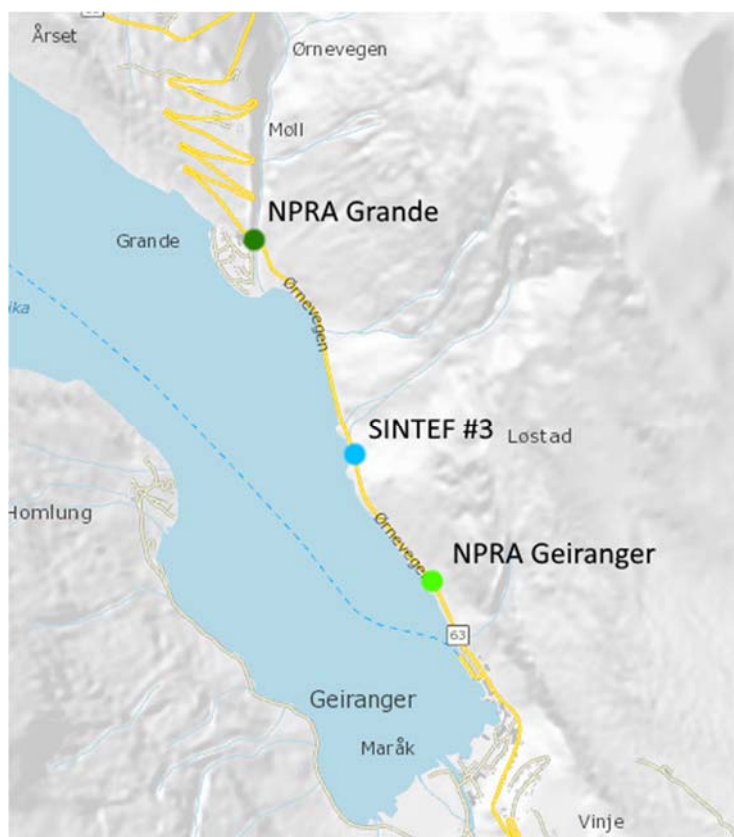
Figure 13 The two NPRA counting sites at Grande and Geiranger are both measuring the same road stretch as SINTEF recording unit #3.

Detailed graphs for the three sites in both directions are shown in Figure 14. The Y axis shows the number of vehicles, while the X-axis shows the active hours of the SINTEF unit (08:00 to 18:00 each of the four days shown). The SINTEF unit is marked with blue colour, while the NPRA sites are different shades of green.

As the graphs shows, all three counting sites delivered very similar data, but none were identical to the others. This can be because of various error sources in both the NPRA sites and the SINTEF units, or because vehicles only drove a part of the road, and/or turned around (there is at least one turning spot slightly north of the SINTEF unit).

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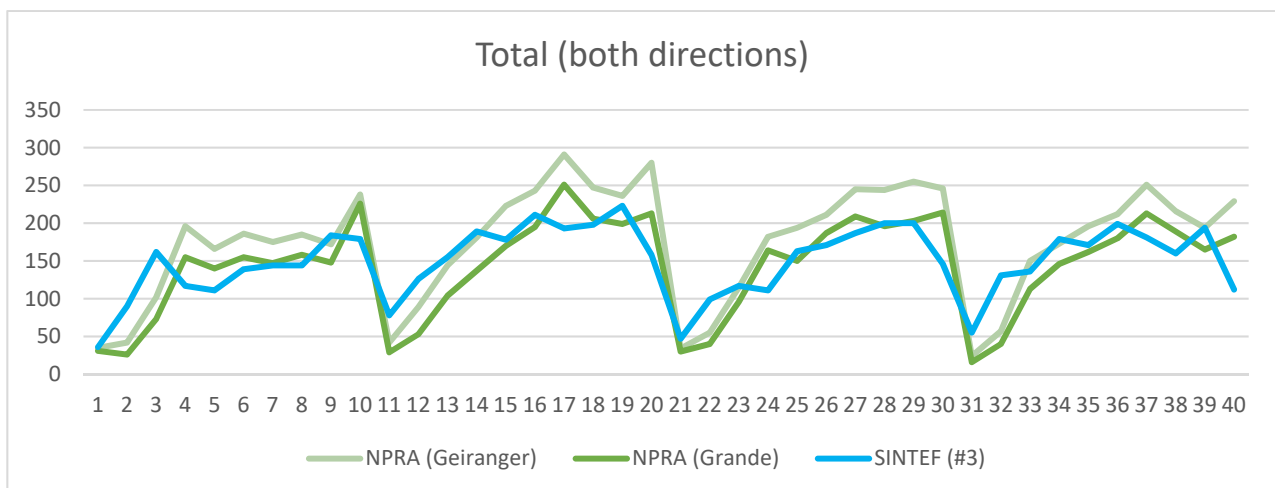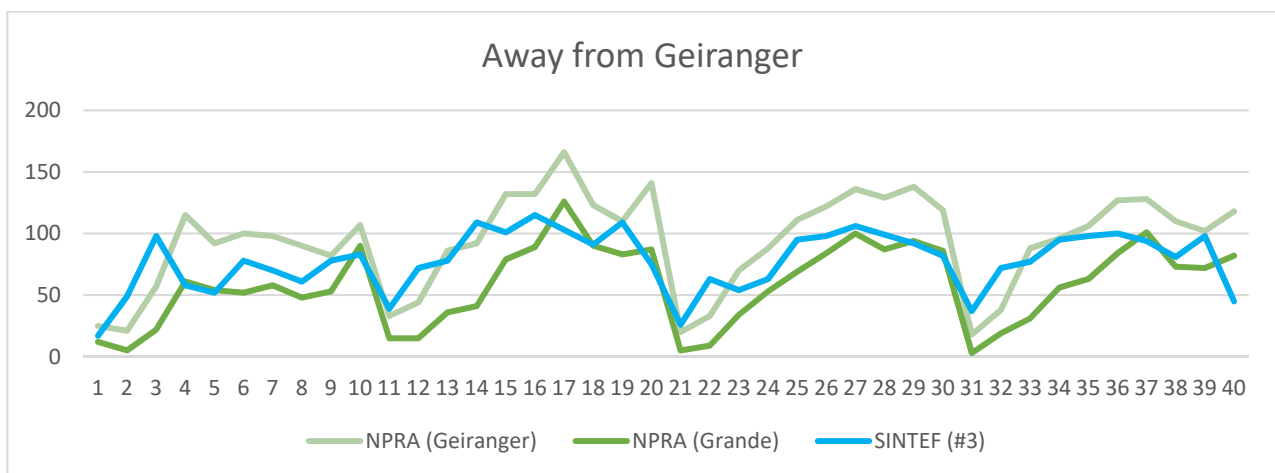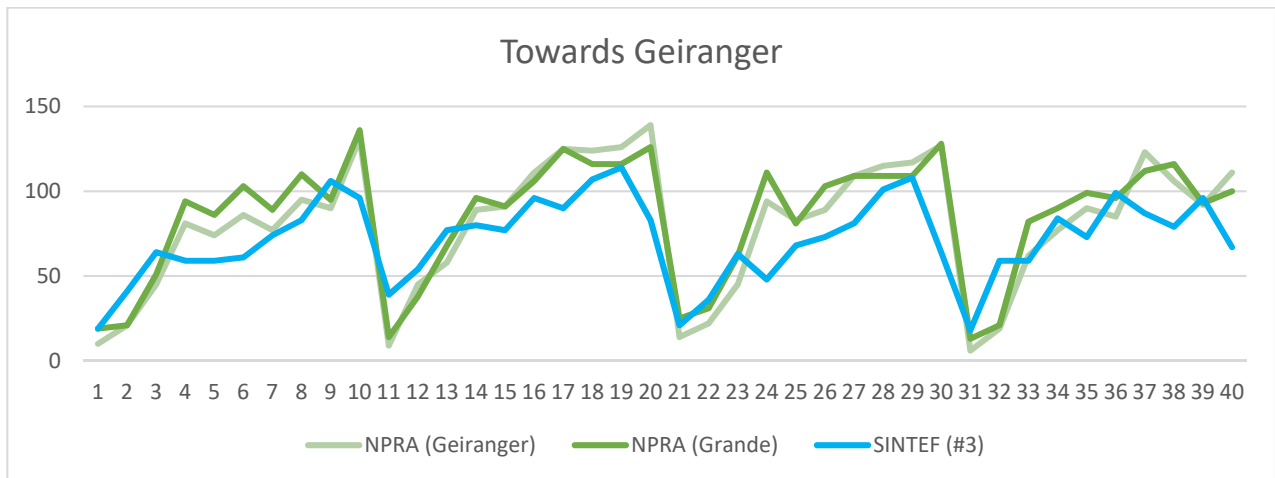
Figure 14 Data from the two NPRA counting sites (shades of green) and the SINTEF recording unit (blue) plotted together. The Y axis shows the number of vehicles passing, while the X axis is the active hours of the SINTEF recording unit (10 hours each day for four days). Top: the lane towards Geiranger. Middle: the lane away from Geiranger. Bottom: the sum of both lanes.

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5 Findings and conclusions

5.1 Findings from the experiment

As mentioned earlier, the use of video recordings and automated analyses to derive traffic counts in Geiranger was twofold: To provide traffic count to the SUSTRANS project, and to gain further experience with the newly developed automated system for video analyses. The SUSTRANS recordings conducted in the summer of 2017 provides SINTEF with valuable experience regarding the configuration of equipment used for recording, and factors affecting the quality of the recordings.

During the initial analysis, it was discovered that some of the units were located in suboptimal locations. Originally, it was planned to mount the units at the top of lamp posts, but this was not feasible within the available data collection budget. Therefore, the units were mounted on tree trunks, rock walls and in store windows. In many cases this gave good results, but due to the improvised nature of the mountings, some units were placed too near or too far from the traffic, or at suboptimal angles.

The SUSTRANS video recordings have provided valuable experience regarding factors such as the position of the camera relative to the road section to be covered in the recording, e.g. distance, altitude and angle of the camera. Based on the experience from the current work, the units should be placed around 10 meters from the road, preferably high up, and with as close as 90 degrees on the traffic direction. The road segment to be recorded should be as straight as possible where the camera is positioned.

The analysis system in its current condition is found to be best suited for counting vehicles, and still needs some work to be able to reliably classify the different types of movement. There are some tiny electric vehicles available for rent in Geiranger, which often confused the classifiers because they can look like both motorbikes and small cars. In addition to this, different types of vehicles (motorbikes, small car, large cars) with hangers and/or luggage on the roof were frequent, and could be classified as both light vehicles, heavy vehicles or campers by the algorithms.

5.2 Future activities

The recording units should be made more robust to prevent data loss. The controllers used in Geiranger proved to be very stable, but unfortunately there were several issues with the batteries. Either switching the batteries or adding a hardware watchdog (a unit that reboots the controller if it misbehaves) could help mitigate these issues. Furthermore, the app used to aim the cameras needs a better way communicating with the controller. For security reasons it should not be wireless, but some kind of cable that extends through the box. This would allow the camera to be aimed while it is fastened, making it much easier to get good recordings.

The traffic counts documented here are separated into five categories. A more detailed classification of object types, for example to distinguish buses from heavy goods vehicles or bikers from motorbikers could be attained by replacing the classical AI algorithms with a more modern algorithm, for example deep learning. This could also improve tracking smaller objects (such as pedestrians), especially when moving in groups.
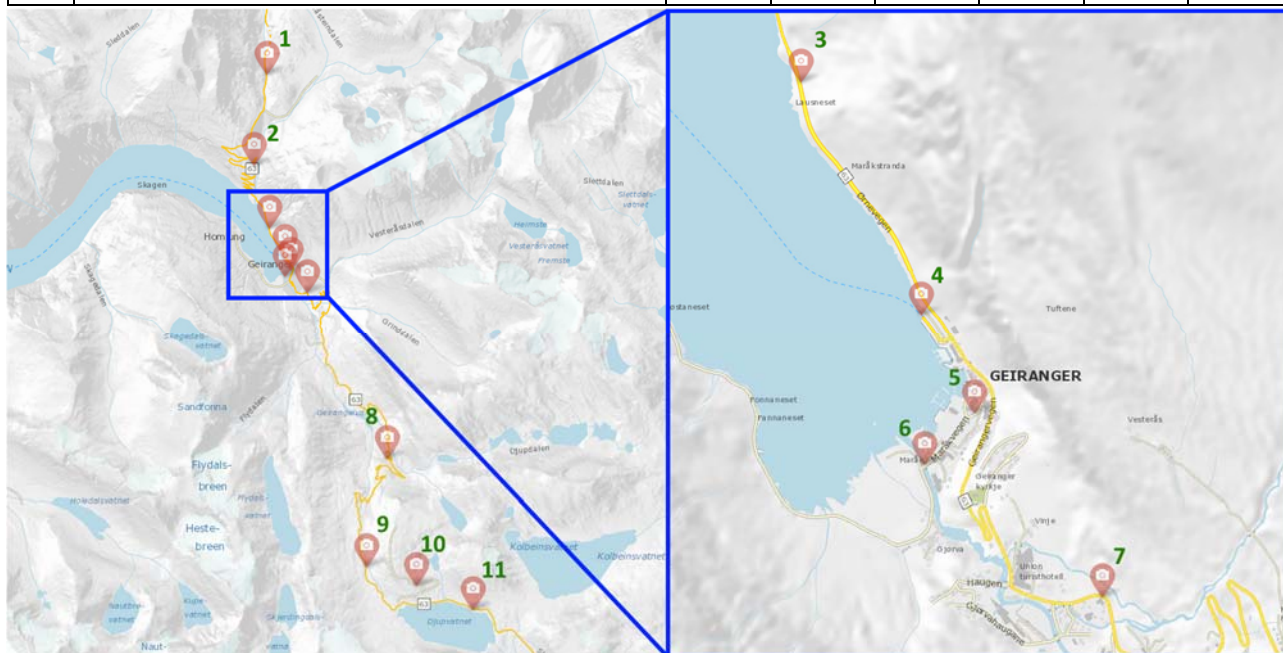
An upgrade of the tracking and classifying algorithms would probably also result in more accurate object detection and tracking, which would make the estimated object sizes (such as vehicle length) and speed much more accurate.

Ideally the system should be able to perform the analysis live, to remove the need for storing any video files at all. This will make the devices much less of a privacy risk, as they will only need to store completely anonymized counting data instead. This is also easier to implement with a modern AI algorithm, as better tracking and classification methods reduces the need for post-recording calibration.

There will be SUSTRANS activity in Geiranger in 2018 as well, which may include some additional recording units for further testing and data collection. In this case we will try to improve the camera placements to give better results, and place multiple cameras at the same road stretch for redundancy and self-validation. These recordings will be performed at a more optimal time of the year, as close to the traffic peak as possible. Since detailed counting of large groups of people proved difficult, we may also test a new system which attempts to measure the crowding of an area instead of providing detailed counts.

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A Resulting counts per recording site

Recording unit		Recording hours, week 32, 2017					
#	Description	Total	Su	Mo	Tu	We	Th
1	North of the parking lot above Ørnesvingen	41	1	10	10	10	10
2	Ørnevegen	1	1	0	0	0	0
3	Between the ferry quay and Fjord Hotel	41	1	10	10	10	10
4	Ferry quay	41	1	10	10	10	10
5	Geiranger Galleri	39	1	8	10	10	10
6	The bridge at Geiranger Camping	20	1	9	10	0	0
7	Gildetun	41	1	10	10	10	10
8	The bends at Kvanndalsfossen	1	1	0	0	0	0
9	North of Dalsnibba	35	1	10	10	10	4
10	The road to Dalsnibba	1	1	0	0	0	0
11	South of Dalsnibba	41	1	10	10	10	10

The recording sites have ascending numbers from north to south - see map.

Results from automatic traffic count are based on video recordings from each individual unit. Section 4.2 gives a more detailed description of each site, and an assessment of the quality of the resulting numbers. The results presented in this appendix must be used with caution, as they are the outcome of methods under development.

The following sections present these results per recording site, where the registrations allow:
- Total counts by direction and mode, for August 6, 17-19; August 7-10, 08-18
- Total counts by direction and hour
- Counts of predominant object type by direction and hour

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A.1   North of the parking lot above Ørnesvingen

Registration site #1: Total counts by direction and mode, August 6, 17-19; August 7-10, 08-18

Total	← Away from Geiranger	→ Towards Geiranger	Total
🚗 Light vehicles	1 864	1 418	**3 282**
🚌 Heavy vehicles	138	277	**415**
🚐 Campers	204	361	**565**
🚲 Bikes	219	95	**314**
🚶 All classes	**2 425**	**2 151**	**4 576**

Camera placement: In the woods west of the road.

Registered movements between 08:00 and 18:00
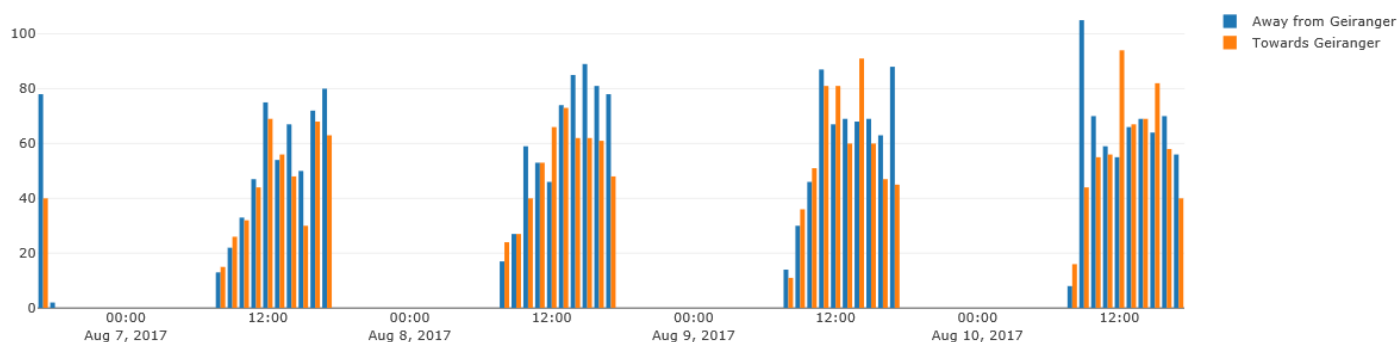
Registration site #1: Total counts by direction and hour

Registered movements between 08:00 and 18:00 of type 'Light vehicles'
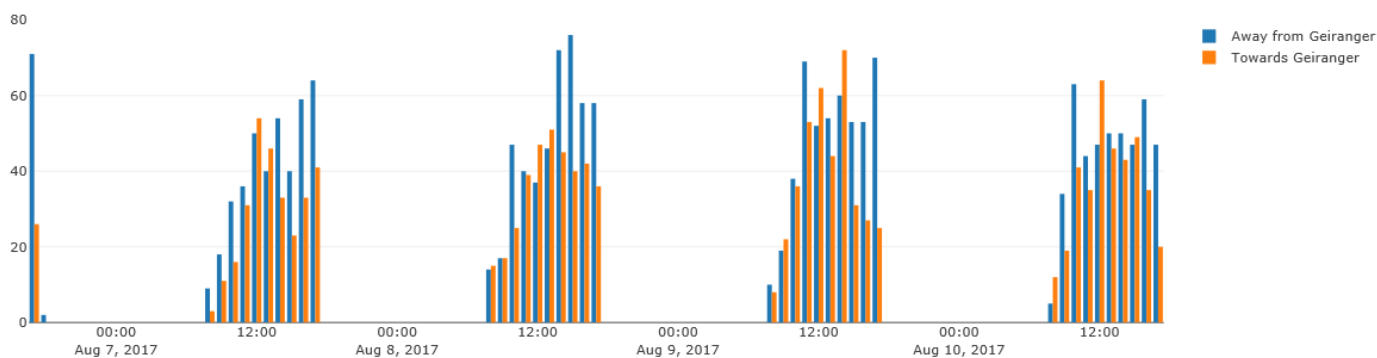
Registration site #1: Counts of light vehicles by direction and hour

A.2 Ørnevegen
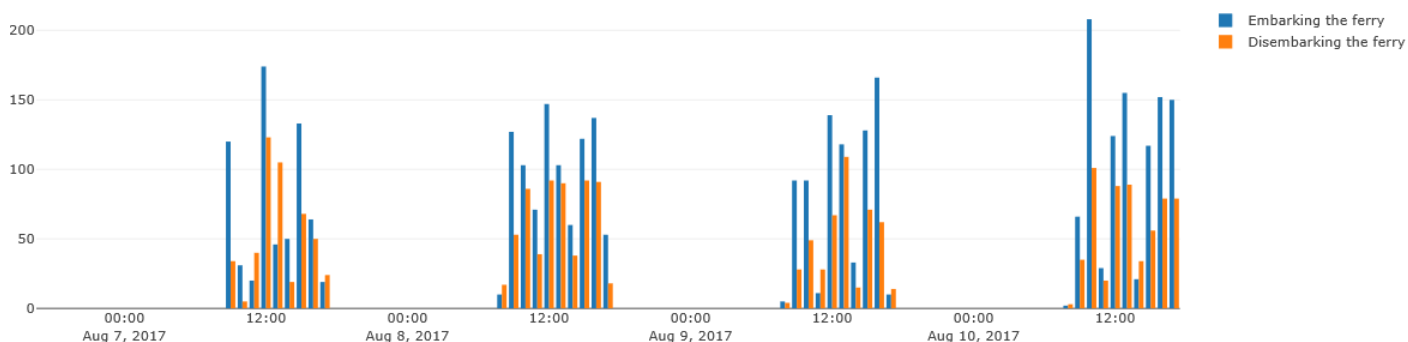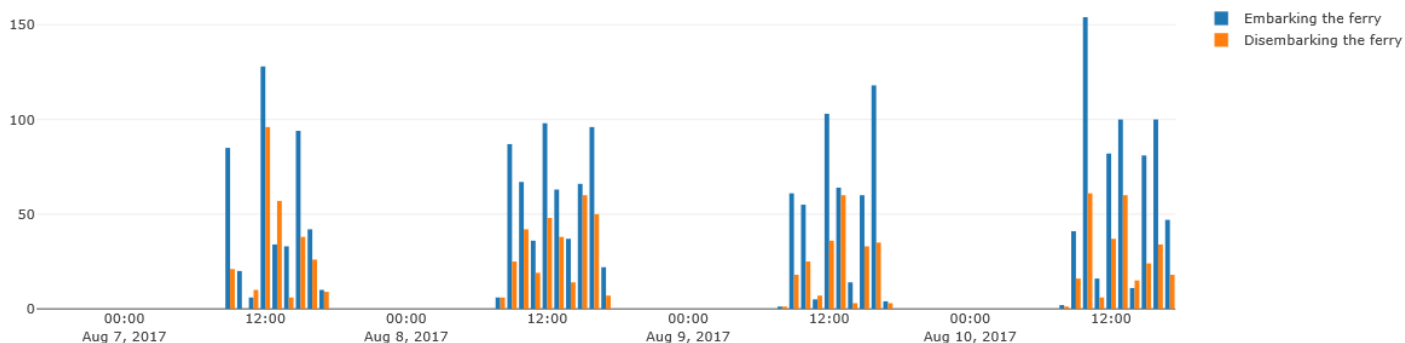
Registration site #2: Total counts by direction and mode, August 6, 17-19

Total ▾	← Towards Geiranger	→ Away from Geiranger	Total
🚐 Campers	17	15	**32**
🚌 Heavy vehicles	7	11	**18**
🚗 Light vehicles	59	81	**140**
🚲 Bikes	5	1	**6**
🚏 All classes	**88**	**108**	**196**

Camera placement: In the woods east of the road.

Due to technical failure, no recordings are available for August 7-10.

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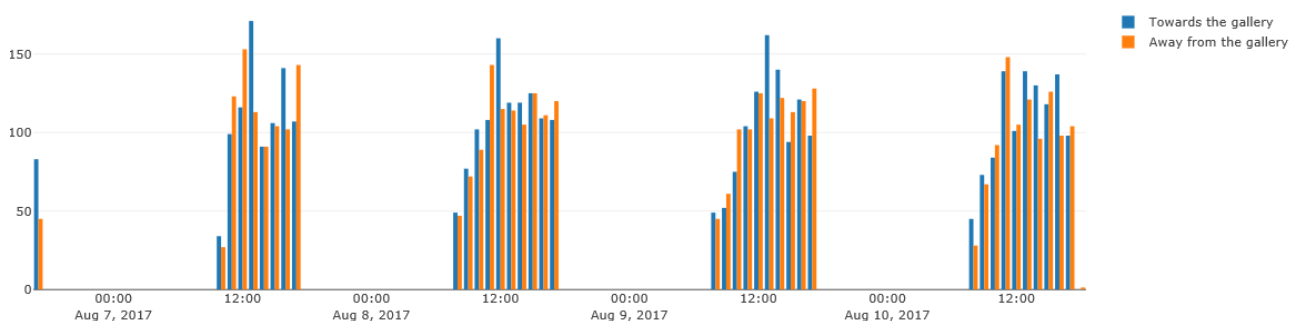1.0

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A.3 Between the ferry quay and Fjord Hotel

Registration site #3: Total counts by direction and mode, August 6, 17-19; August 7-10, 08-18

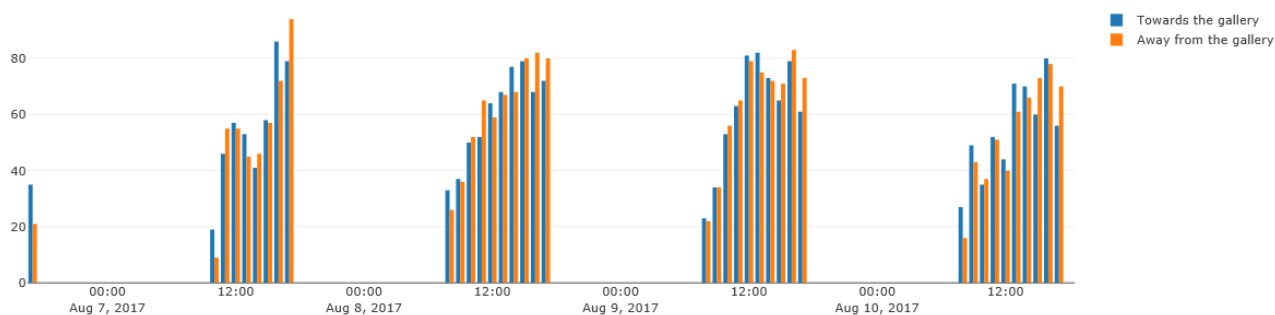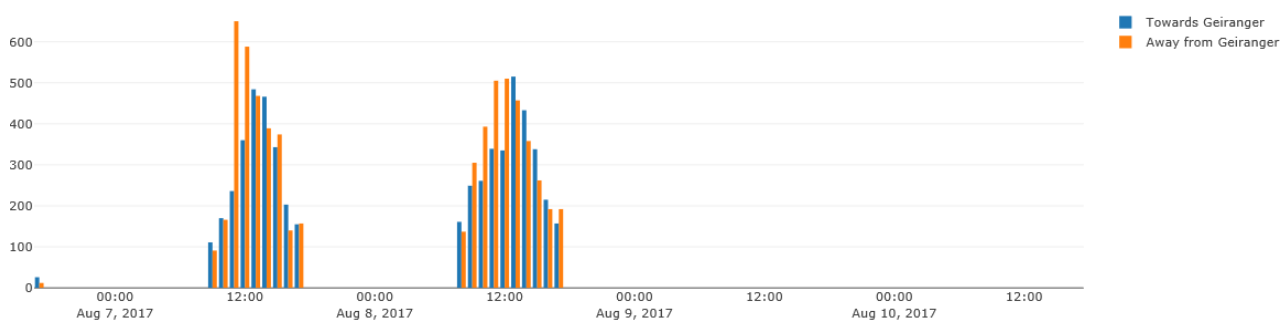| Total	← Towards Geiranger	→ Away from Geiranger	Total
🚗 Light vehicles	2 671	2 628	**5 299**
🚌 Heavy vehicles	288	277	**565**
🚶 Persons	216	252	**468**
🚲 Bikes	498	587	**1 085**
🚐 Campers	240	79	**319**
🚶 All classes	**3 913**	**3 823**	**7 736**

Camera placement: In the woods on the east side of the road.

Registered movements between 08:00 and 18:00
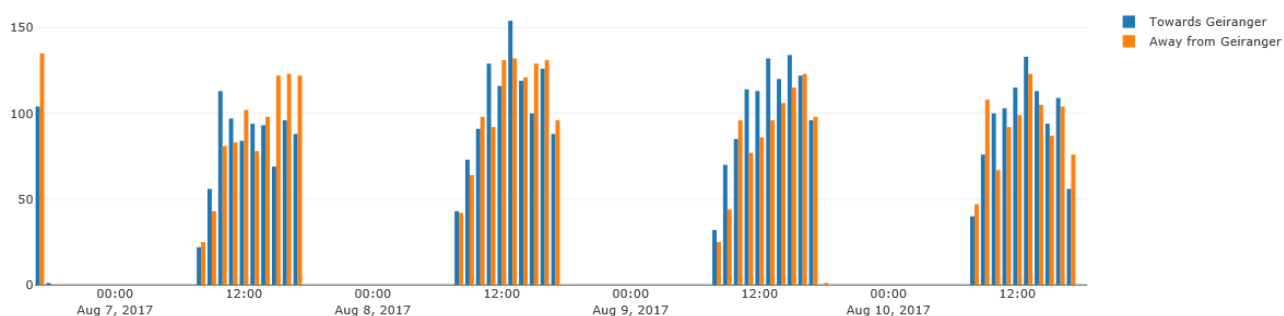
Registration site #3: Total counts by direction and hour

Registered movements between 08:00 and 18:00 of type 'Light vehicles'
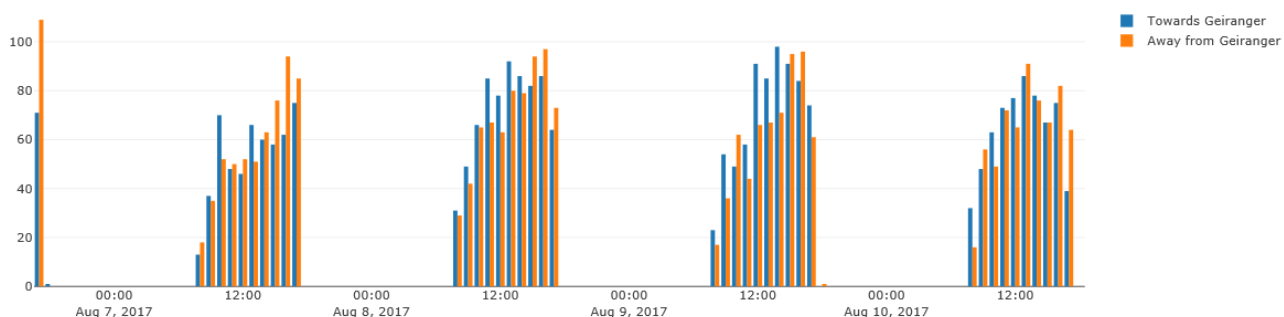
Registration site #3: Counts of light vehicles by direction and hour

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A.4 Ferry quay

Registration site #4: Total counts by direction and mode, August 7-10, 08-18

Total	→ Embarking the ferry	← Disembarking the ferry	Total
🚶 Persons	2 149	1 065	**3 214**
🚗 Light vehicles	334	244	**578**
🚚 Heavy vehicles	298	343	**641**
🚐 Campers	627	463	**1 090**
🅰 All classes	**3 408**	**2 115**	**5 523**

Camera placement: In the woods on the east side of the road.

Registered movements between 08:00 and 18:00

Registration site #4: Total counts by direction and hour

Registered movements between 08:00 and 18:00 of type 'Persons'

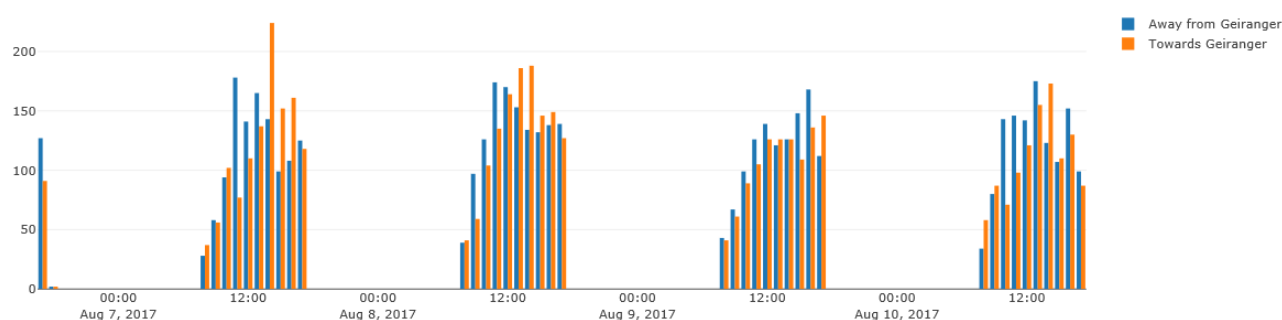*Registration site #4: Counts of persons by direction and hour*

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A.5   Geiranger Galleri

Registration site #5: Total counts by direction and mode, August 6, 17-19; August 7-10, 08-18

Total	⬇ Towards the gallery	⬆ Away from the gallery	Total
🧍 Persons	1 144	998	**2 142**
🚗 Light vehicles	2 232	2 234	**4 466**
🚐 Heavy vehicles	79	125	**204**
🚐 Campers	453	451	**904**
🏍 Bikes	201	147	**348**
🔭 All classes	**4 109**	**3 955**	**8 064**

Camera placement: In the attic window of the gallery building.

Registration site #5: Total counts by direction and hour

Registration site #5: Counts of light vehicles by direction and hour

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A.6 The bridge at Geiranger Camping

Registration site #6: Total counts by direction and mode, August 6, 17-19; August 7-8, 08-18

Total ▼	← Towards Geiranger	→ Away from Geiranger	Total
🚶 Persons	4 993	5 565	**10 558**
🚐 Campers	222	304	**526**
🚗 Light vehicles	339	477	**816**
🚲 Bikes	3	0	**3**
🔭 All classes	**5 557**	**6 346**	**11 903**

Camera placement: On a fence south of the bridge.

Registered movements between 08:00 and 18:00

■ Towards Geiranger
■ Away from Geiranger

Registration site #6: Total counts by direction and hour

Registered movements between 08:00 and 18:00 of type 'Persons'

■ Towards Geiranger
■ Away from Geiranger
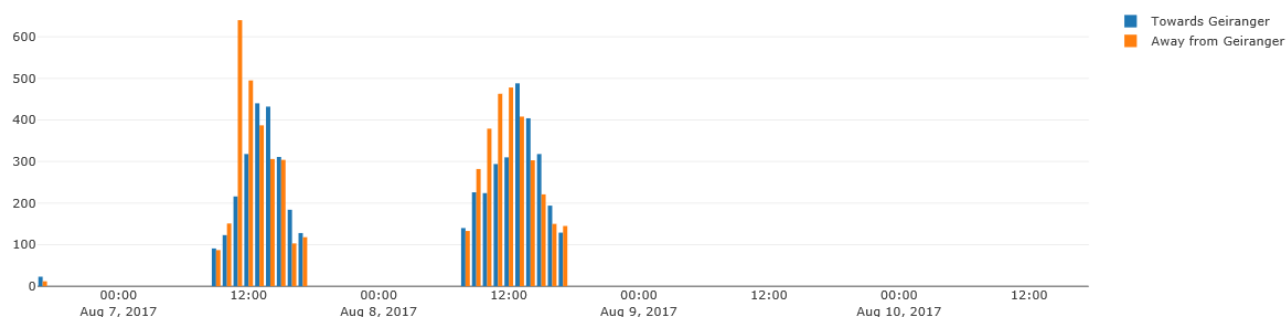
Registration site #6: Counts of persons by direction and hour

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A.7 Gildetun

Registration site #7: Total counts by direction and mode, August 6, 17-19; August 7-10, 08-18

Total	→ Away from Geiranger	← Towards Geiranger	Total
🚗 Light vehicles	3 278	3 150	**6 428**
🧍 Persons	470	568	**1 038**
🚐 Campers	353	183	**536**
🚲 Bikes	287	421	**708**
🚌 Heavy vehicles	532	399	**931**
🚶 All classes	**4 920**	**4 721**	**9 641**

Camera placement: In the attic window of the Gildetun community house.

Registered movements between 08:00 and 18:00

Registration site #7: Total counts by direction and hour

Registered movements between 08:00 and 18:00 of type 'Light vehicles'
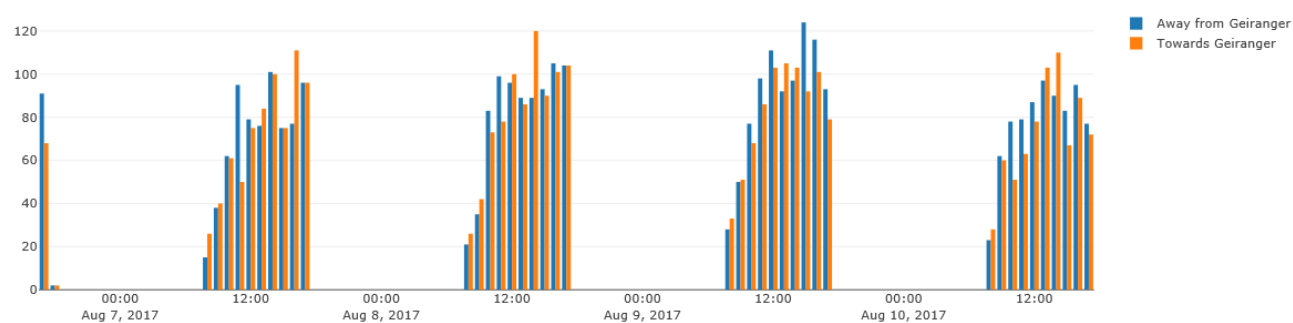
Registration site #7: Counts of light vehicles by direction and hour

A.8   The bends at Kvanndalsfossen

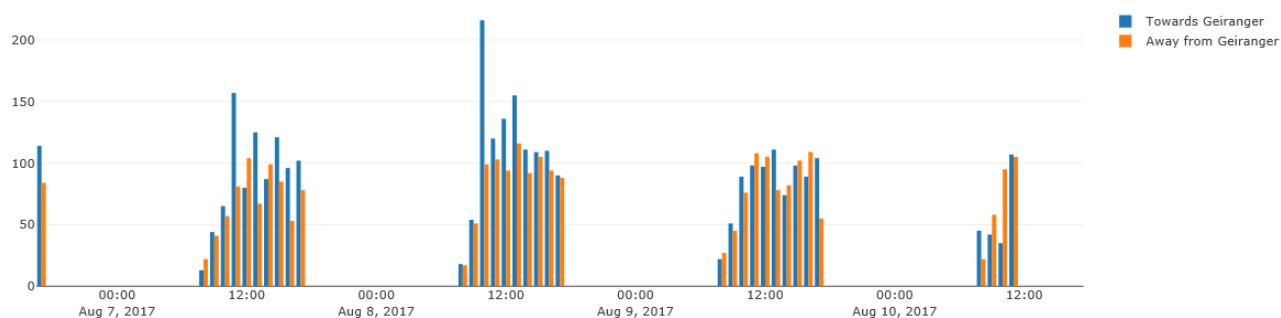*Registration site #8: Total counts by direction and mode, August 6, 17-19*

Total ⌄	← Towards Geiranger	→ Away from Geiranger	Total
🚗 Light vehicles	63	60	**123**
🚲 Bikes	3	1	**4**
🚐 Campers	6	9	**15**
🚌 Heavy vehicles	2	0	**2**
🚶 **All classes**	**74**	**70**	**144**

Camera placement: In the woods south of the road.

Due to technical failure, no recordings are available for August 7-10.

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A.9 North of Dalsnibba

Registration site #9: Total counts by direction and mode, August 6, 17-19; August 7-10, 08-18

Total ▾	→ Towards Geiranger	← Away from Geiranger	Total
🚗 Light vehicles	1 551	1 706	**3 257**
🚌 Heavy vehicles	465	223	**688**
🚐 Campers	230	254	**484**
🚲 Bikes	375	256	**631**
undefined	563	256	**819**
🚶 Persons	1	2	**3**
🚶‍♂️ All classes	**3 185**	**2 697**	**5 882**

Camera placement: On a hill east of the road.

Registered movements between 08:00 and 18:00

Registration site #9: Total counts by direction and hour

Registered movements between 08:00 and 18:00 of type 'Light vehicles'
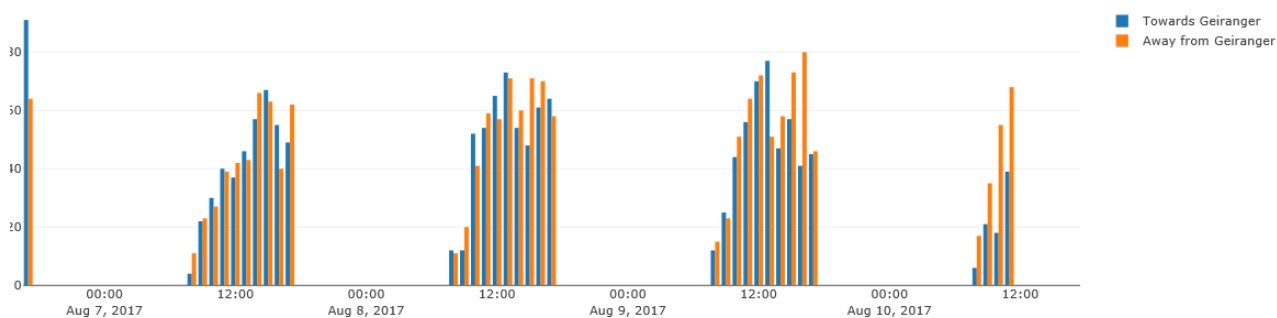
Registration site #9: Counts of light vehicles by direction and hour

A.10 The road to Dalsnibba

Registration site #10: Total counts by direction and mode, August 6, 17-19

Total	← Towards Dalsnibba	→ Away from Dalsnibba	Total
🚗 Light vehicles	27	20	**47**
🚲 Bikes	2	5	**7**
🚶 Persons	0	5	**5**
🚐 Campers	4	3	**7**
🚌 Heavy vehicles	2	1	**3**
🚘 All classes	**35**	**34**	**69**

Camera placement: In the mountain side north of the road.

Due to technical failure, no recordings are available for August 7-10.

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A.11 South of Dalsnibba

Registration site #11: Total counts by direction and mode, August 6, 17-19; August 7-10, 08-18

Total ▼	↑ Towards Geiranger	↓ Away from Geiranger	Total
🚚 Heavy vehicles	236	245	**481**
🚗 Light vehicles	1 967	1 988	**3 955**
🚐 Campers	248	340	**588**
🚲 Bikes	176	173	**349**
🏛 All classes	**2 629**	**2 750**	**5 379**

Camera placement: On a hill north of the road.

Registration site #11: Total counts by direction and hour
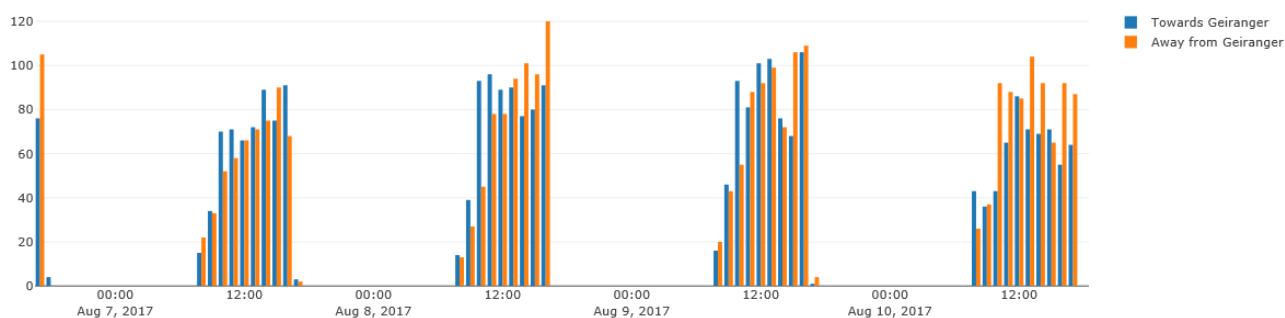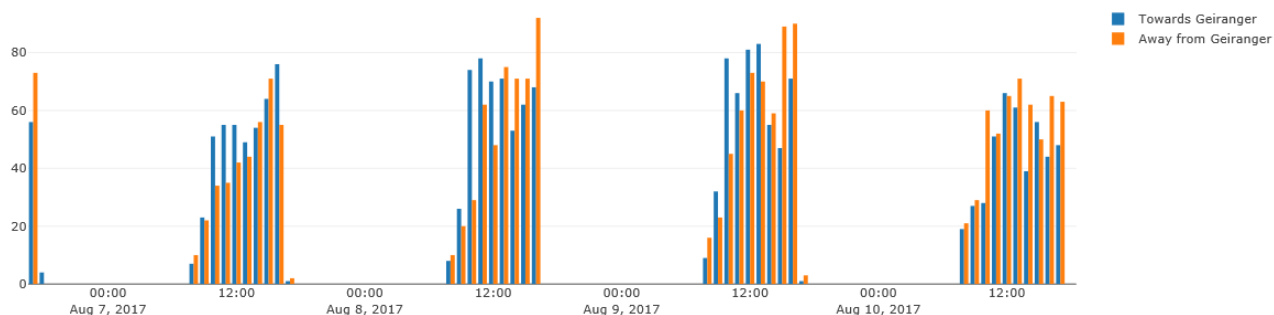
Registration site #11: Counts of light vehicles by direction and hour

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