HIGH-SPEED PLOUGH/ENVIRONMENTAL PLOUGH

P. Gruhs
National Swedish Road Administration, Borlänge, Sweden
pontus.gruhs@vv.se

ABSTRACT

This paper describes the tests that have been conducted on the so-called environmental plough or high-speed plough, as it is also called. Tests have been conducted during two winter seasons at 8 locations in Sweden to find out how the plough performs in various weather situations. These tests have been documented and the drivers have been given the opportunity to provide their opinions about the plough. Selective testing has also been conducted on an airfield and in its surroundings so as to be able to measure full snow removal capability, wear on cutting edges, fuel consumption and noise. The results indicate that a considerable amount of money could be saved by using this new type of plough, while at the same time, a number of aspects concerning the environment could be improved in comparison to use of a conventional plough.

KEYWORDS

PLOUGHING/WINTER ROAD MAINTENANCE

1. INTRODUCTION

The snowploughs used in Sweden are primarily operated at low speeds so as to achieve good results. Consumption of both fuel and cutting edges constitutes a significant cost and an environmental problem. The National Swedish Road Administration, along with the largest contractors, has evaluated and implemented a new type of plough during two seasons. The expectations for the plough have been that it should be capable of high-speed operation and still provide good results. Noise levels, fuel consumption and cutting edge wear were expected to decline with the new type of plough.

That which is new with this new type of plough is that it has flexible mounts for cutting edges and better supporting wheels. Both components are made of polyurethane, which has entailed that the ploughs can move forward at much higher speeds than what is normally the case. Because the plough lacks spring dampers, among other things, it has been made much lighter – about 600 kg lighter than a conventional plough.

Figure 1 – The flexible cutting edge mounts and the environmental plough attached to a lorry.

2. TESTS: WINTERS OF 2007/2008 AND 2008/2009

During the winter of 2007/2008, the environmental plough was evaluated on 8 routes. A number of advantages were evident even after the first season. Wear on cutting edges was minimal and the plough could be operated at very high speeds at most locations and still produce good results. Testing during season 1 also showed that a number of components required corrective measures.

After a few components (such as undersized bolts) were replaced, additional tests were conducted on 8 routes during the winter of 2008/2009, as well as a more concentrated test on an airfield during the same winter. A number of parameters were evaluated, both by the drivers and the project manager.

Part 1 – An assessment made by the drivers
– How well the snow is pushed aside
– Top speed for operation but with retained good results
– Working environment regarding the formation of clouds of snow
– Comprehensive assessment of the ploughing round

Part 2 – An assessment made by the project manager
– Maintenance costs per plough
– Which cutting edge is used and how many times it has been replaced
– Measurement of the cutting edge, how much has worn away
– How often the components require replacement and how quickly this can be done
– The condition of road signs and other objects before and after the winter season

2.1. Opinions from the drivers

– It takes less time (about 10 minutes) to replace the cutting edge on the environmental plough in comparison to replacement on a conventional plough, which takes about 25 minutes

– Replacement of cutting edge is made 30 percent less often

– Traffic queues seldom form behind the vehicle

– The environmental plough is perceived as quieter
– The plough works best with wet snow
– Problem with clouds of snow rising over the cab

– With dry snow, the plough has a harder time in getting a "grip". The plough requires snow pressure on the plough blade to plough effectively.

3. TESTS ON THE AIRFIELD AND IN SURROUNDING AREA

The following tests were conducted:

- Full snow removal performance specified as snow depth before and after ploughing.
- Cast height and cast length of the removed snow.
- Noise levels outdoors
- Noise levels in the vehicle cab
- Fuel consumption when ploughing roads
- Cutting edge wear when ploughing roads

4. RESULTS FROM TESTS ON THE AIRFIELD AND IN SURROUNDING AREA

4.1. Full snow removal performance

The environmental plough was run on a newly asphalted airfield and compared with a conventional plough at three speeds, 30/50/70 km/h.

Measurements were conducted before and after ploughing with the two ploughs.

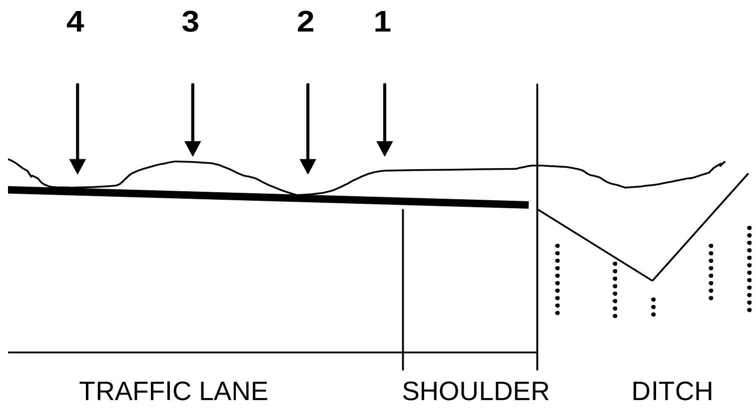

Figure 2 – Measurements conducted at four locations per run.

The average values of 4 snow-depth measurements have been used.

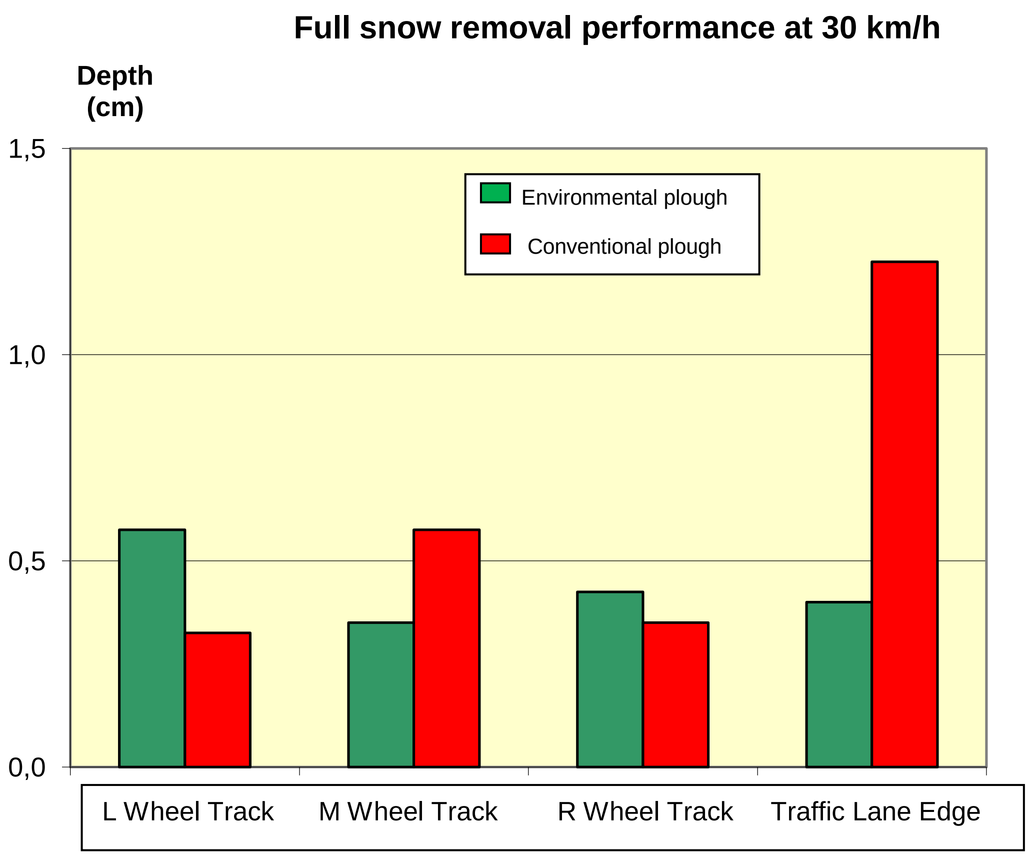

Figure 3 – Full snow removal performance. The average values for snow depth after 4 ploughings at 30 km/h

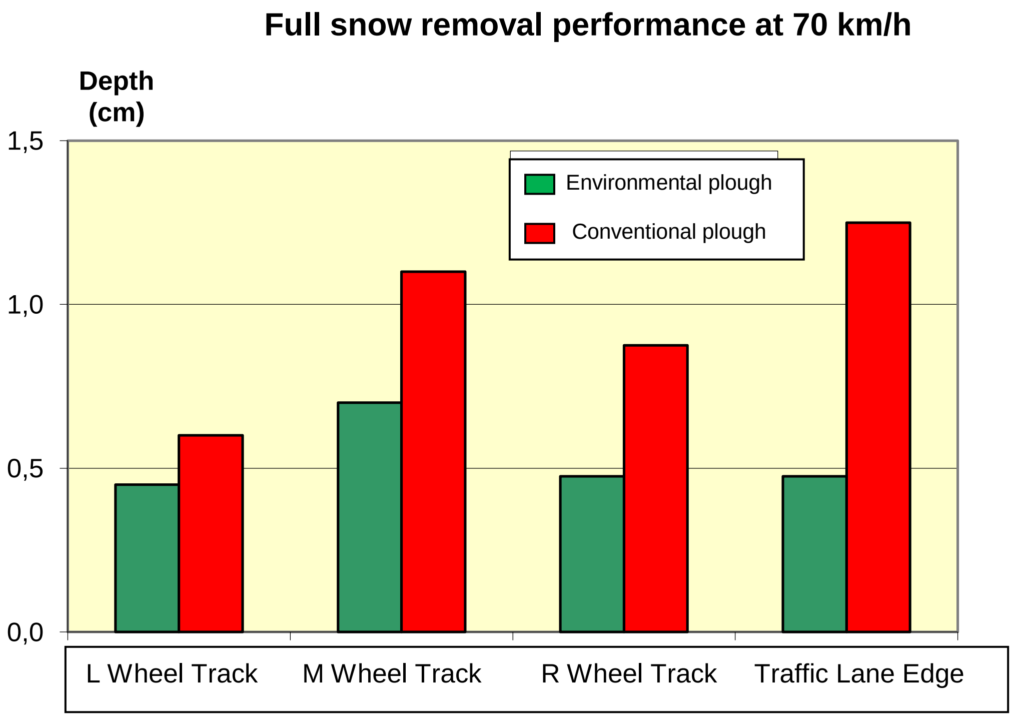

Figure 4 – Full snow removal performance. The average values for snow depth after 4 ploughings at 70 km/h

4.2. Noise

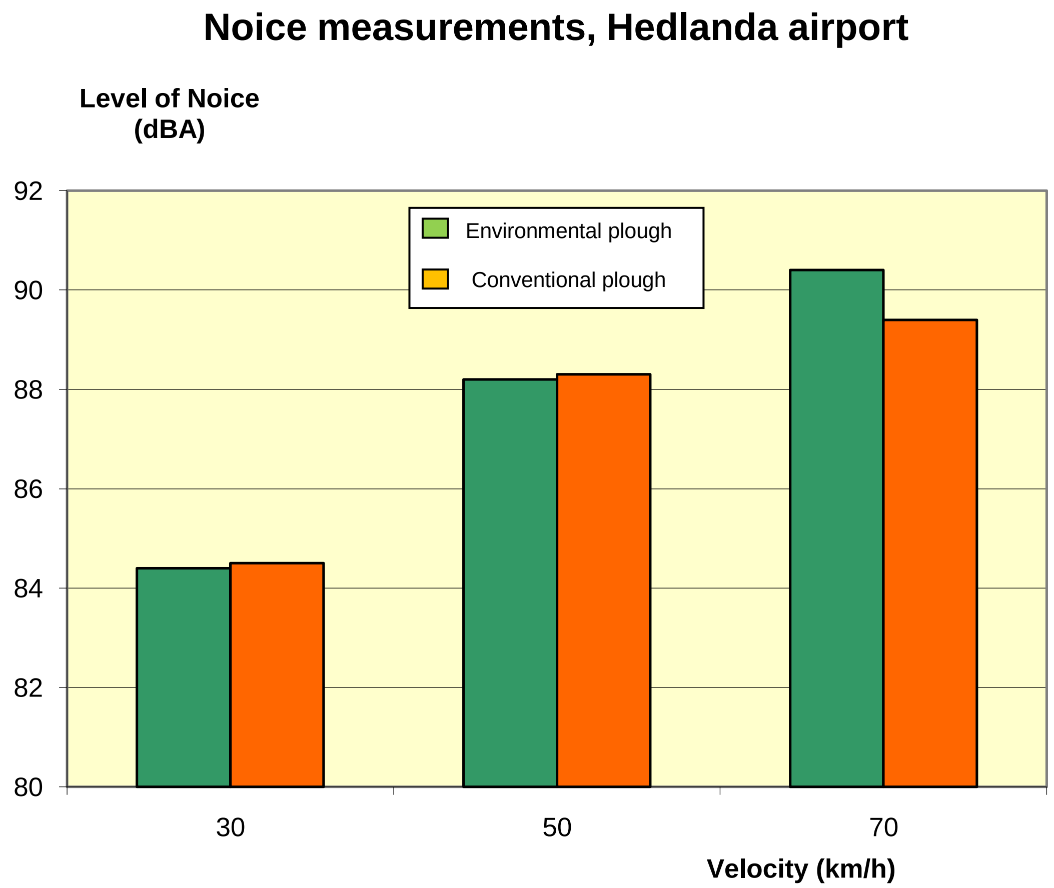

Figure 5 – Noise levels measured on airfield. Average values of three passes and two directions. The road surface was coated with a thick layer of ice with a thin layer of packed snow in patches.

As seen, the difference between the two different ploughs is insignificant, with a maximum of 1 dBA.

During noise measurement on a normal road the surface was snowless with small strips of packed snow according to figure 6.

Figure 6 – Road surface on highway 84 during measurement.

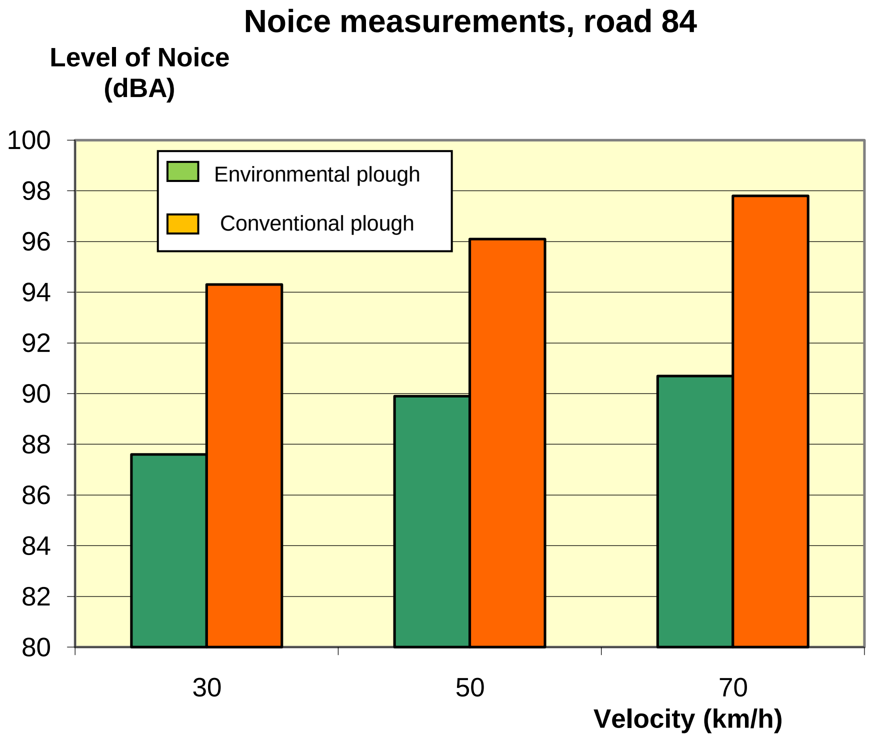

Figure 7 – Noise levels measured on highway 84. Average values of one pass in each direction for each speed. The road surface was snowless with small strips of packed snow.

The difference between the two different ploughs is significant for these measurements. The environmental plough has a 6–7 dBA lower noise level.

4.3. Fuel consumption

Measurements of fuel consumption were conducted on a 44-km long loop consisting of:

- An uphill grade
- A steep uphill grade
- A downhill grade
- Two level sections

The targeted speeds during the loop run were 40 and 70 km/h. On the steepest uphill grade, however, a speed of 70 km/h could not be maintained; the speed there instead ranged between 50 and 60 km/h.

The road surface during measurement was rutted with no snow in the wheel tracks but with packed snow beyond according to Figure 8.

Figure 8 – Road surface on highway 315 during fuel consumption measurement.

Two equipment failures occurred while measuring fuel consumption. After about 70 percent of the loop had been completed during measurements at 40 km/h, the left support wheel loosened on the environmental plough. The same thing also occurred after about 50 percent of the loop had been driven at 70 km/h with the environmental plough. This entails that the environmental plough's left section was in direct contact with the ground for extended periods, while the reference plough could be operated with both support wheels intact.

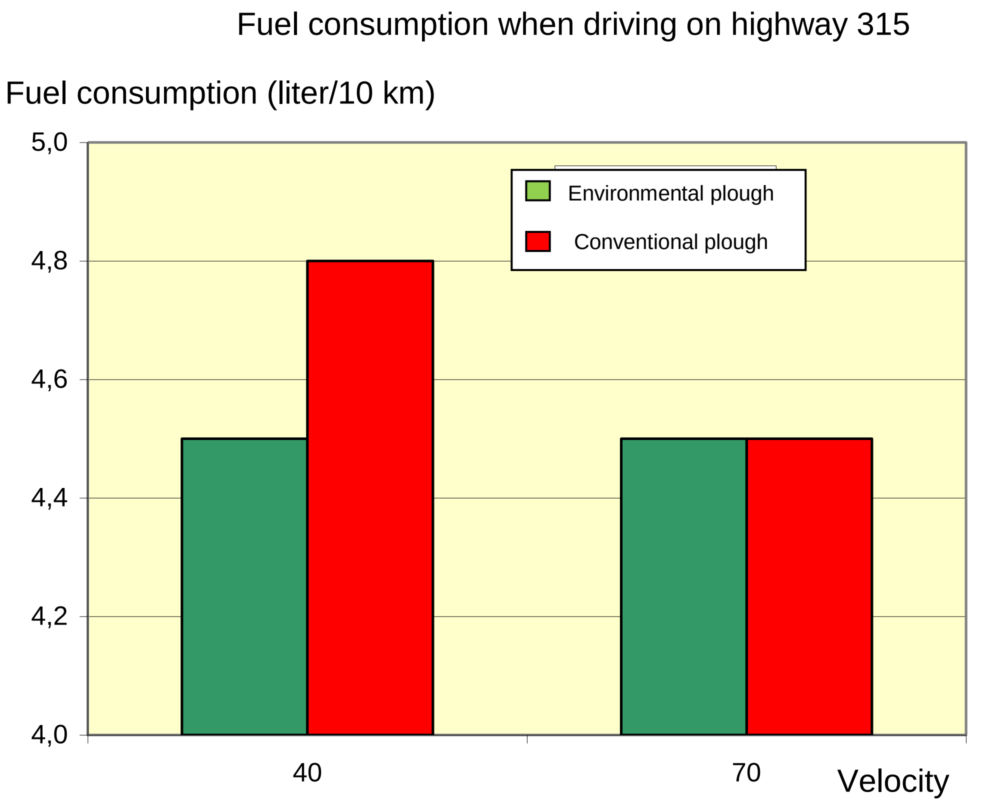

Figure 9 – Measured fuel consumption after 44 km on highway 315. The road surface was rutted with no snow in the wheel tracks but with packed snow beyond.

After having driven about one-third of the first round at 40km/h with the environmental plough and having managed the steep uphill grades, the plough vehicle driver observed that fuel consumption to this point was at about 1 litre per 10 km lower than when the same stretch was driven with the reference plough. This gives an indication that the fuel consumption for the environmental plough may have been substantially overestimated due to the failures.

4.4. Cutting edge wear

Wear of cutting edges is calculated by measuring the distance on each of the four cutting edges between the lower mounting holes and the cutting edge's lower edge before and after the plough vehicle has driven both loops, i.e. a distance of almost 2 times 44 km = 87 km. See Figure 9.

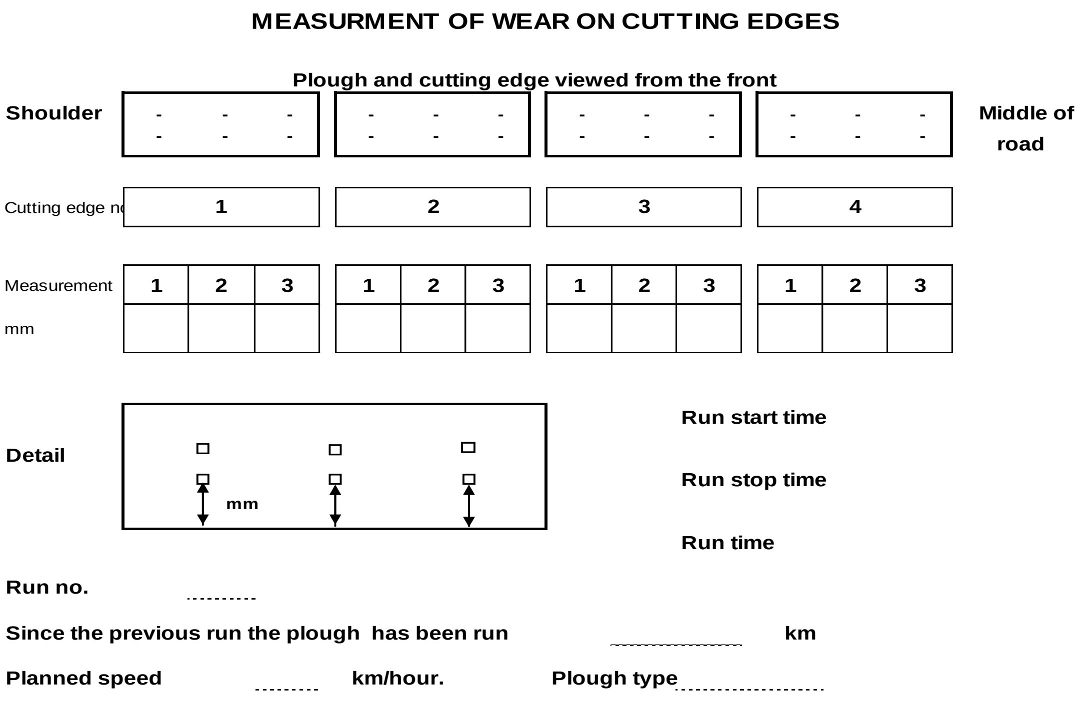

Figure 10 – Measurement method for wear of cutting edges. From the left in the figure, the first cutting edge (no. 1) is the one closest to the edge of the roadway.

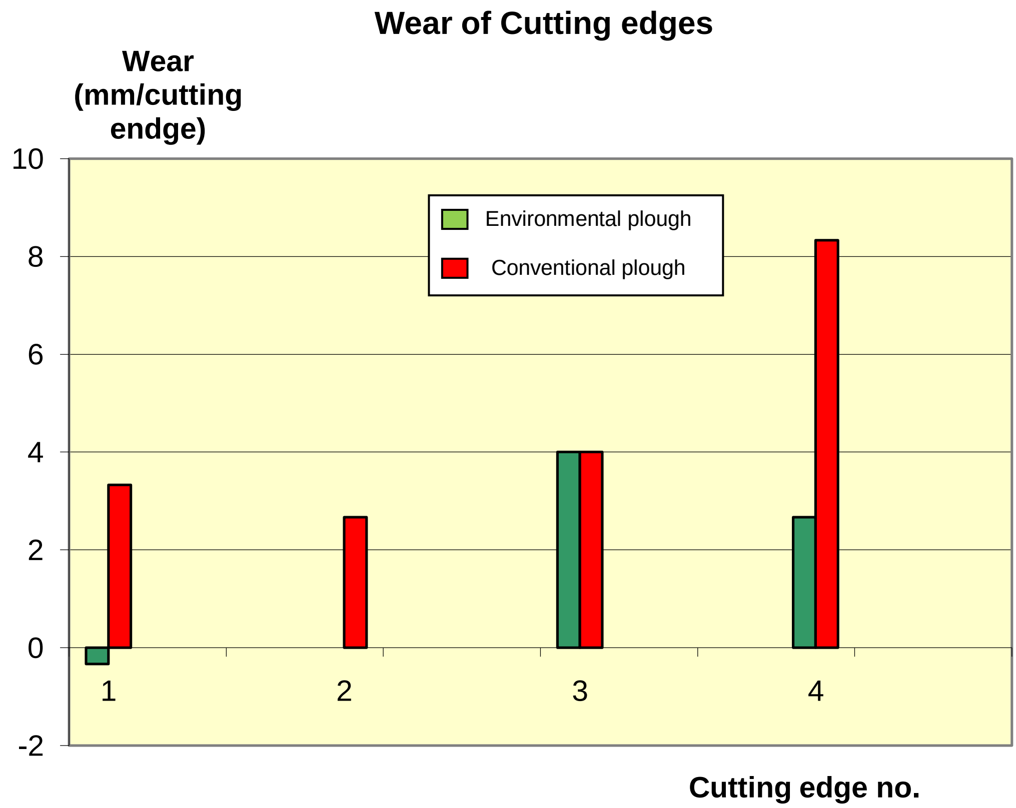

Figure 11 – Measured wear as averages for cutting edge nos. 1–4 after about 87 km on highway 315. The road surface was rutted with no snow in the wheel tracks but with packed snow beyond.

As can be seen in Figure 9, average wear on the environmental plough's cutting edges 1 and 2 (those closest to the edge of the roadway) was insignificant. Wear on cutting edge nos. 3 and 4 was significantly higher, about 3–4 mm after two rounds. Wear on the reference plough's cutting edges averaged between 3 and 8 mm after two rounds.
A calculation of cutting edge wear per kilometre resulted in about 0.018 mm for the environmental plough and about 0.053 mm for the reference plough, i.e. about 3 times as much steel was worn away on the reference plough in comparison with wear with the environmental plough.
The amount of wear on the environmental plough's cutting edge nos. 3 and 4 that was due to the support wheel loosening and the cutting edge being in direct contact with the road surface cannot be assessed. It is clear, however, that cutting edge wear on the environmental plough is overestimated.

4.5. Miscellaneous

Pressure on the front axle declines by 1.2 tons with the use of the environmental plough in comparison to an equally large conventional plough.

5. ECONOMY

A calculation has been made regarding economy for one operational area (there are about 140 operational areas in Sweden) and the results are presented below.

In Sweden, roads are divided into 5 classes according to:

Traffic flow	Class
≥ 16,000	1
8,000 - 15,999	2
2,000 - 7,999	3
500 - 1,999	4
< 500	5

The environmental plough is expected to primarily be used on larger roads – the roads that are salted, i.e. classes 1–3. On class 2 roads, the average speed is expected to increase from 20 to 50 km/h on two-thirds of the road distances and from 40 to 70 km/h on one-third of the road distances. On class 3 roads, the average speed is expected to increase from 35 to 45 km/h.

Costs for combination operation on the road network in standard classes 2 and 3 during one winter with a conventional ploughs is SEK 1,250,000/winter and SEK 825,000/winter with environmental ploughs.

The environmental plough’s higher removal speed also entails that the plough rounds can be extended without exceeding execution times. The total number of contracted vehicles can be reduced from 8 to 6 on class 2 road networks and from 4 to 3 on class 3 road networks. The fixed cost for one vehicle is SEK 130,000/winter. For a reduction with 3 vehicles, the savings would be about SEK 450,000/winter.

When the number of contracted vehicles is reduced, the need for buying or leasing ploughs and salt-spreaders is also reduced by a corresponding amount. The depreciation period is set at 10 years. Purchase prices for one plough and one salt-spreader are presumed to be SEK 150,000 and SEK 400,000, respectively, and the maintenance costs SEK 7,000/winter and SEK 330,000/winter, respectively. Purchase, maintenance and depreciation for 3 ploughs and 3 salt-spreaders are then approximately SEK 275,000/winter.

Cutting edge wear is about 0.05 mm/km for a conventional plough and about 0.01 mm/km for the environmental plough. The cost for a conventional plough is SEK 37,000/winter and SEK 7,000/winter for an environmental plough.

6. CONCLUSIONS

The total cost for winter road maintenance declines by about SEK 1,200,000 for each operational area (Sweden consist of about 140 operational areas). Cost for motorists in the form of reduced queue times, faster and better road conditions, and less fuel consumption have not been included in the calculations.

Noise levels are 6–7 dBA lower with the environmental plough in comparison to conventional ploughs.

Wear to road markings have not been measured.

There are two reasons why the environmental plough is expected to improve winter road maintenance. The first is that it is easier. The second is that the cutting edge mounts and wheels are made of polyurethane. The cutting edge mounts have an aggressive cutting angle and have the property of being flexible. The cutting edge mounts are sufficiently flexible to take up lesser irregularities on roads as well as larger irregularities, such as bridge joints and manhole covers, without breaking. This entails that higher speeds can be maintained without endangering the safety of the drivers, but at the same time, with good snow removal capabilities. After the first year, a number of plough components had failed, but after these problems were rectified operation was satisfactory. It can be said with certainty that the plough can be used where the rules stipulate “black roads”, i.e. roads that are to be salted (classes 1–3). We are not entirely certain whether the plough functions satisfactorily on the smaller road network that is not salted.