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ROAD MAINTENANCE IN FINLAND AND GERMANY

Bachelor's Thesis 2011

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Tämän opinnäytetyön tarkoituksena oli selvittää teiden kunnossapitoa, olosuhteita ja menetelmiä kahdessa eri maassa, Suomessa ja Saksassa. Tutkimus tehtiin vertailemalla. Tutkimuksen tarkoitus oli antaa yleiskuva teiden kunnossapidosta, sekä teiden kunnossapidolle asetetuista vaatimuksista ja teiden kunnossapitoon vaikuttavista olosuhteista.

Opinnäytetyössä tutkittiin tieverkkoja, liikennemääriä, sääolosuhteita, kunnossapitovaatimuksia, teiden kunnossapito-organisaatioita, teiden kunnossapidon toteuttamista, talvikunnossapitoa sekä kustannuksia. Toimenpiteet ja vaatimukset on käsitelty yleisellä tasolla, ainoastaan talvikunnossapito sisältää tarkempia laatuvaatimuksia.

Teoria on kerätty alan kirjallisuudesta ja aikaisemmista tutkimuksista. Se koostuu tekstistä, jota tukevat ja kuvaavat kuvat, tilastot ja kuvaajat. Jokainen luku joka käsittelee sekä Suomea että Saksaa, ja sisältää yhteenvedot, joissa teoriaa on analysoitu ja suoritettu vertailua poislukien organisaatioita koskeva luku.

Opinnäytetyö sisältää vertailutaulukon, joka antaa nopeasti yleisvaikutelman teiden kunnossapidossa olevista eroista ja siihen vaikuttavista erilaisista olosuhteista Suomessa ja Saksassa.

Asiasanat: Tieverkot, teiden kunnossapito, talvikunnossapito

ABSTRACT
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The purpose of this thesis was to study road maintenance, circumstances and methods in two different countries, Finland and Germany. The research was made by comparison.

The thesis examined the road networks, traffic loads, weather conditions, road maintenance requirements, organizations, implementation, winter maintenance and costs. The measures and requirements were introduced in general level, only winter maintenance includes more specific quality requirements.

The theory was gathered through relevant literature and previous studies. It consists text, figures and tables to demonstrate the statistics and other theory. Each chapter which concerns both Finland and Germany includes summaries where the theory is evaluated and compared, excluding the chapter concerning the organizations.

The thesis includes a comparison table, which gives an expression concerning differences on the field of road maintenance and circumstances affecting it.

Keywords: Road network, road maintenance, winter maintenance

CONTENTS

1 INTRODUCTION

As long as there will be roads, there will also be road maintenance. This means that it is always a topical issue and therefore it has to be developed constantly to make sure the fluency and safety of the traffic.

Before starting the comparison, the reader must realize that there are many basic things which have a great effect on road maintenance, for example geographical location of the countries and the population, which is over 15 times bigger in Germany than in Finland and location. Author's own working experiences in the field of road maintenance have shown that there are three main things affecting maintenance operations, which are also partly the result from the things mentioned before. These are the existing road network, traffic volumes and weather conditions. Because of this the first three chapters concern these themes. There is also a comparison of implementation of the road maintenance in this thesis. Because of strong winters, both in Finland and Germany in this millennium, winter maintenance is decided to include in the thesis as an independent chapter, separated from the other maintenance measures.

The goal of this thesis is to find out the requirements and circumstances of road maintenance in these two countries to find out how different circumstances affect operations and determine the differences.

The road maintenance requirements will be introduced on general level excluding winter maintenance, which will be examined more specifically because of the difficulties on it in the past few years, especially in Germany.

The information will be based on the literature and previous researches.

2 THE ROAD NETWORKS

All roads in one area build up together a road network. These roads must fulfill different tasks and they have various functions. Functions can be, for example wide, regional or local connections, development of a certain area or functions of inhabitancy. These are the reasons why there are different classifications for the roads. (Wolf 2005)

2.1 Finland

Roads are especially significant in Finland, because it has a large surface area but it is sparsely populated. What's more, from the viewpoint of central Europe, Finland is located on the margins. Most exports to this most important market area are transported by sea. From the standpoint of the competiveness of industry and commerce, functional logistics are vital, especially the functionality of the internal transportation system. Road transport accounts for 67 % of total freight transport. (Snow & Ice Databook 2010, p. 81)

The Finnish road network comprises highways, municipal streets and private roads. The entire network extends for some 454 000 kilometers of which 350 000 kilometers are private and logging roads and 26 000 kilometers street networks. In 2010 Finnish Transport Agency is in charge of 78 161 kilometers of highways. The formation is shown in table 2.1. 65 %, 50 958 kilometers, of the all roads are paved. Pedestrian and bicycle routes amounted to 4 884 kilometers. (Finnish Transport Agency)

Table 2.1 The roads Finnish Transport Agency is in charge of

Class I main roads	8 568 km	11,0 %
Class II main roads	4 760 km	6,1 %
Regional roads	13 537 km	17,3 %
Connecting roads	51 295 km	65,6 %

As shown in the table, the main roads are divided into first-class highways and second-class highways. In 2010 the main roads accounted for 13 328 kilome-

ters, including 765 kilometers motorways and 110 kilometers semi-motorways intended for motor vehicles only.

Finland is divided into nine districts (the Regional Centres) which are responsible for the ordering of the road maintenance of their own area under guidance of the central unit. They are illustrated in figure 2.1. (Centre for Economic Development).

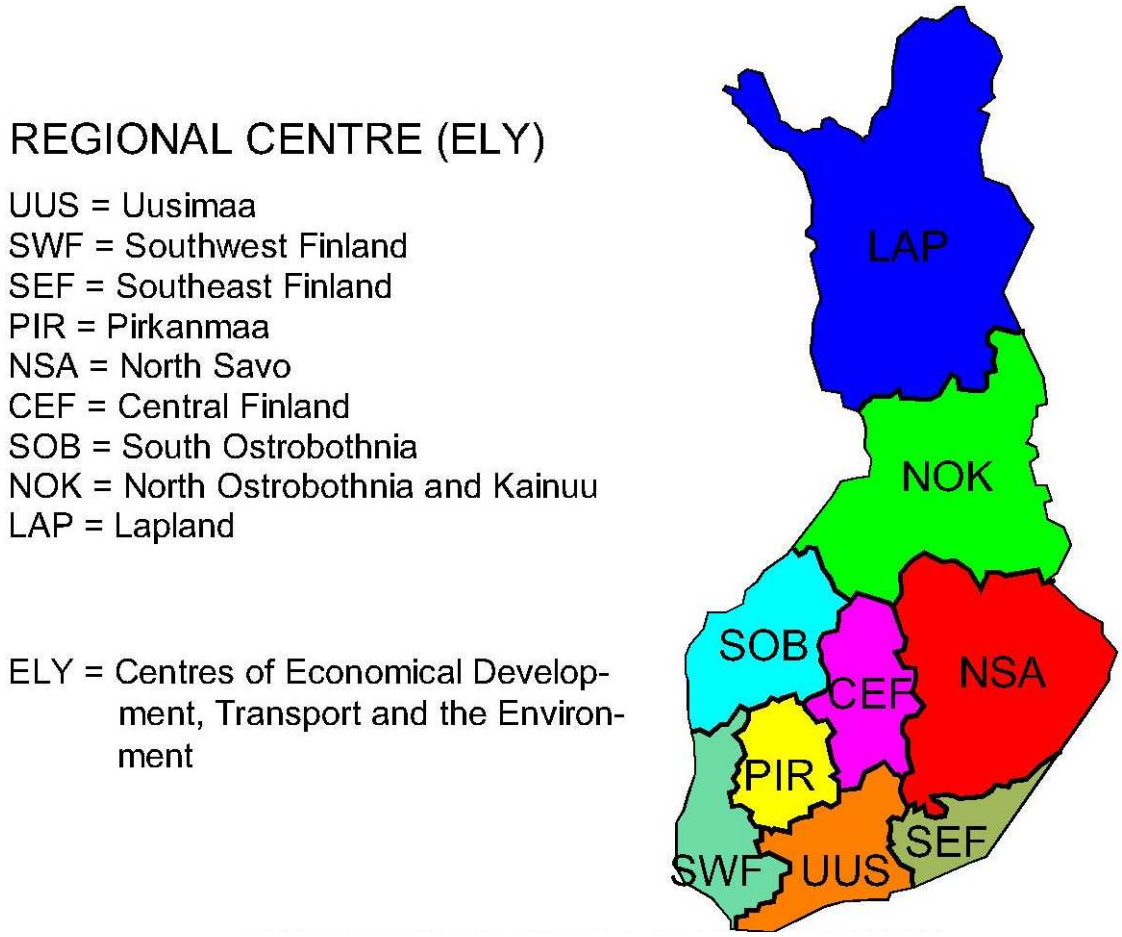


Figure 2.1 The map of Centres of Economic Development, Transport and the Environment (Centre for Economic Development)

It is shown in the figure that there are nine different Regional Centres that are also road maintenance managers. Table 2.2 illustrates the lengths of the roads in every Regional Centre.

The table shows that the highways are divided quite equally between the different regions. The biggest difference is the length of the connecting roads in region North Savo.

Table 2.2 The lengths of the roads in Regional Centres (Finnish Road Statistics 2009)

Regional Centre	Class I Highways (km)	Class II Highways (km)	Regional Roads (km)	Connecting Roads (km)	Motor-ways* (km)	Semi-motorways* (km)
UUS	1 068	402	1 438	6 227	421	42
SWF	718	345	1 023	5 931	104	1
SEF	584	88	657	2 844	27	17
PIR	533	300	771	3 403	89	19
NSA	1 293	905	2 884	10 864	42	3
CEF	688	348	886	3 395	14	2
SOB	922	577	1 368	5 814	11	1
NOK	1 497	775	2 367	8 160	36	17
LAP	1 295	1 021	2 143	4 658	17	7

*****Included in highways

It is remarkable that most of the motorways and a big part of the semi-motorways are in Uusimaa, although the total length of these roads in Finland is considerably small.

2.2 Germany

In Germany, the road network comprises motorways, (Autobahnen), which are illustrated in figure 2.3, federal highways (Bundesstrassen), state roads (Landestrassen), district roads (Kreisstrassen) and municipal roads (Gemeindestrassen). The motorways and federal highways belong to the federation as the road maintenance authority according to the Federal Highway Act. However, they are managed by the management of the federal states. Also according to the Federal Highway Act, the state roads, district roads, municipal roads and other public field roads and forest roads are looked after by the road maintenance authorities of the federal states, districts and cities or municipalities. The freeways, federal highways, state roads and district roads form the network of the higher classified roads. (Wolf 2005)

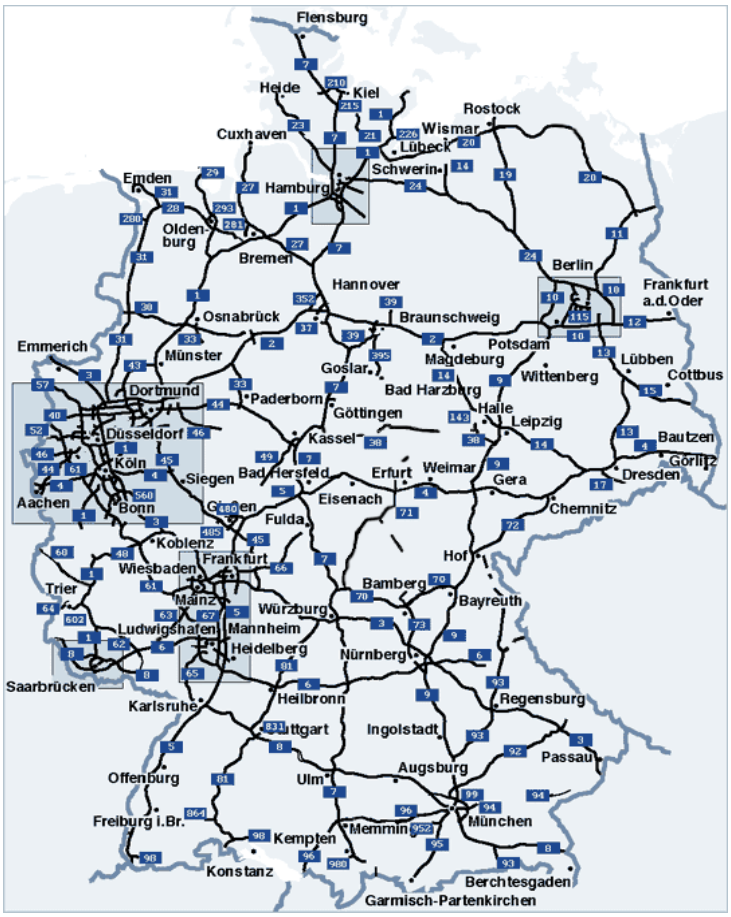


Figure 2.2 Motorway Network in Germany (Federal Ministry of Transport, Building and Urban Development)

On the 1st of January 2010, the road network of the higher classified roads comprised totally 230 970 km, including the new federal states. The formation is shown in table 2.3.

Table 2.3 German road network of higher classified roads (Statistiches Bundesamt Deutschland)

motorways	12 813 km	5,5 %
federal highways	39 887 km	17,3 %
state roads	86 616 km	37,5 %
district roads	91 654 km	39,7 %

In addition to these roads seen above, there are still municipal roads with the total length of 395.400 km (Statistiches Bundesamt Deutschland) . The motorway network comprises motorways with 2 – 3 lanes less than 1 %, 4- 5 lanes 77 %, 6 – 7 lanes 21 % and 8 or more lanes 1 % (Kathmann 2007, p. 11). It is remarkable, that municipal roads comprise around 63 % of the total road net-

work. The area of paved roads comprises only 1,2 % of Germany's total area. (Wolf 2005)

Germany is divided into 16 federal states (Bundesländer) which are also the road maintenance managers (Beckers 2006). They are illustrated in figure 2.4.

Figure 2.3 Federal States of Germany (University of Leipzig)

The new states are Berlin, Mecklenburg-Vorpommern, Saxony-Anhalt, Brandenburg, Thuringia and Saxony. The area of these states formed the old German Democratic Republic and they were united to the Federal Republic of Germany in 1990 (Saarela 2002). That is also one the main reasons why the road network in Germany has not been divided equally. Most of the roads are centered on the area of the old Federal Republic of Germany. The distribution of the road lengths is shown in table 2.4

Table 2.4 Distribution of the roads in Germany between states (Statistiches Bundesamt Deutschland)

State	Motorways (km)	Federal Highways (km)	State Roads (km)	District Roads (km)
BW	1 046	4 362	9 942	12 074
BAV	2 503	6 549	14 027	18 805
B	77	169	0	0
BRA	795	2 814	5 805	2 977
BRE	75	44	0	0
H	81	120	0	0
HE	972	3 070	7 151	4 961
MVO	552	1 985	3 304	4 158
LSA	1 431	4 826	8 307	13 670
NRW	2 200	4 768	12 833	9 751
RP	872	2 948	7 226	7 393
SAA	240	334	845	626
SAX	531	2 430	4 778	5 826
SAN	407	2 232	4 021	4 295
SHO	533	1 560	3 687	4 120
THU	498	1 676	4 690	2 998

The table shows that the highest road lengths are concentrated on Bavaria, Lower Saxony, North Rhine Westphalia and Baden-Württemberg. The lengths of the roads in Bremen, Berlin and Hamburg are very small which can be explained by the small area of these states because they are so called city-states. On the other hand, in new states the lengths of the roads are notably smaller than in old states. Furthermore, it is worth to notice that the lengths of the motorways in Bavaria and North Rhine Westphalia are much bigger than in other states.

2.3 Summary

There is a huge difference in the road networks between Finland and Germany. The total length of the road network is almost 3 times longer in Germany. Also the total length of the motorways in Germany is over 16 times bigger than in Finland. Furthermore, 21 % of them have 6-7 lanes, which sets huge demands to road maintenance compared to Finland. It is notable that most of the motorways in Finland are in Uusimaa, while in Germany the dividing is not as big as in Finland. The length of the Federal Highways in Germany is over 4 times bigger than Class I Highways in Finland. These facts lead automatically to larger volume of work and higher total costs in road maintenance.

There are approximately 27 000 kilometers of gravel roads in Finland. This is peculiarity compared to Germany because there all the higher classified roads are paved. This is also one difference that different kind of road network gives to the road maintenance measures.

3 TRAFFIC VOLUMES

3.1 Finland

The average daily number of automobiles on all highways was about 1 260 in 2009. This number is not evenly distributed over the entire road network or between various parts of the country. On main roads the AADT (average annual daily traffic) was from 2 700 to 5 700 automobiles, on regional roads 1 400 and on connecting roads 300. In Uusimaa the AADT was 3 128 automobiles, in the rest of southern Finland from 1.000 to 1.500 and in central and northern Finland from 500 to 1.000. AADT's in regions are shown in figure 3.1. (Finnish Road Statistics 2009).

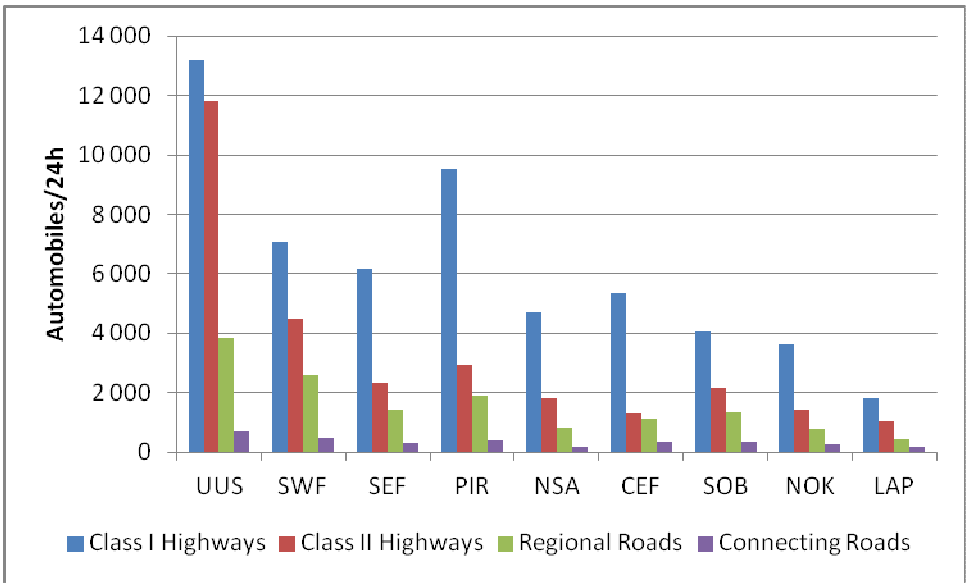


Figure 3.1 AADT in the Regional Centres (Finnish Road Statistics 2009)

The figure shows that the traffic is heavily concentrated on the main roads of southern Finland. In southern Finland there are accordingly almost daily shuttle traffic jams on busy road sections near built-up areas. In the rest of the country congestion occurs mainly during weekends. Only minor part of the daily traffic is concentrated on the connecting roads. Some of these roads are paved with

gravel (35 % of all highways). However, most of the traffic, about 96 %, is on asphalt and oil gravel roads. Gravel roads account for no more than 4 % of the entire highway traffic. (Finnish Road Statistics 2009)

The total mileage was 35 870 billion automobile kilometers, including 63 % on the main roads. The mileage on highways in 2009 is shown in figure 3.2. (Finnish Road Statistics 2009)

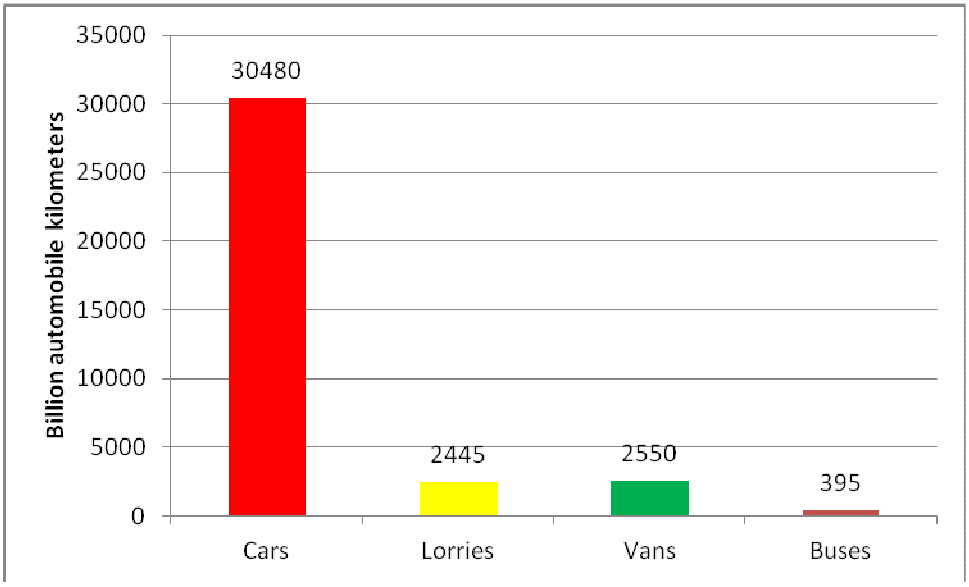


Figure 3.2 Mileage on highways in 2009 (Finnish Road Statistics 2009)

The part of lorries was 6,8 % and buses 1,1 % of the total mileage. Clearly the biggest part of mileage was comprised by cars, 85,0 %.

3.2 Germany

During the past decades Germany faced an enormous increase of traffic on the highways. Motorways in Germany carry more than 40 % of the total traffic road network. The enormous increase of traffic volumes in recent years will continue even more in the future as a consequence of the ongoing political and economic developments, especially the European process of unification. The extension of European Union to the east is expected to bring great amounts of traffic to the "transit-country" Germany within the next years due to intensified economic co-operations. (Snow & Ice Databook 2010, p.102).

A nation-wide road traffic census (RTC 2005) was performed in 2005 as a part of usual five-year cycle to monitor traffic development and to determine the traf-

fic volumes on German trunk roads and motorways. (Kathmann 2007,p. 3). RTC 2010 took place in 2010 but the newest published results in 2011 are from RTC 2005.

In 2005 the AADT in the whole Germany was 47 632 automobiles/24 h on motorways, 9 207 automobiles/24 h on federal highways and 3 803 automobiles/24 h on state roads. There are big differences between the states. The biggest AADT-value was in Berlin (86 750) and in Hamburg (82 047). The highest AADT of the area states was in Hesse (62 516), North Rhine Westphalia (58 149) and Baden-Württemberg (57 956). The only value less than 20 000 automobile/24h was in Mecklenburg-Vorpommern. On federal highways the highest AADT was in Bremen (42 011) followed by Berlin with the value of 26 157 automobiles/24h. In the area states AADT was between 5 432 – 13 420 automobiles/24h, with the biggest value in Baden-Württemberg and the smallest in Brandenburg. (Kathmann 2007, pp. 8-9).

The exact values of AADT are shown in table 3.2. It is notable that in Berlin, Hamburg and Bremen there are no state roads and district roads at all. Additionally, in Lower-Saxony there was no information considering these roads and in Brandenburg, Saxony-Anhalt and Thuringia there is no information available concerning the district roads.

Table 3.1 AADT in federal states (Kathmann 2007, p. 10)

State	Motorways	Federal Highways	State Roads	District Roads
BW	57 956	13 420	5 040	2 892
BAV	47 350	9 424	3 822	1 759
B	86 750	26 157	0	0
BRA	35 741	5 432	2 821	-
BRE	55 769	42 011	0	0
H	82 047	47 224	0	0
HE	62 516	10 574	3 186	1 701
MVO	18 814	6 526	2 750	1 686
LSA	45 010	8 656	-	-
NRW	58 149	10 238	5 176	2 531
RP	38 243	8 570	2 750	1 038
SAA	31 675	9 391	5 171	3 542
SAX	40 498	7 498	3 302	1 372
SAN	42 107	6 407	2 545	-
SHO	39 841	10 166	3 652	2 767
THU	36 247	6 685	3 379	-

The table shows that most of the traffic is concentrated on motorways as mentioned before. The volume of traffic is considerably high in city-states on both freeways and federal state roads.

The total mileage outside cities on freeways, federal highways and state roads was in 2005 402,8 billion automobile kilometers. (Kathmann 2007, p. 11) The distribution of the mileage between different classes of the roads is shown in figure 3.3.

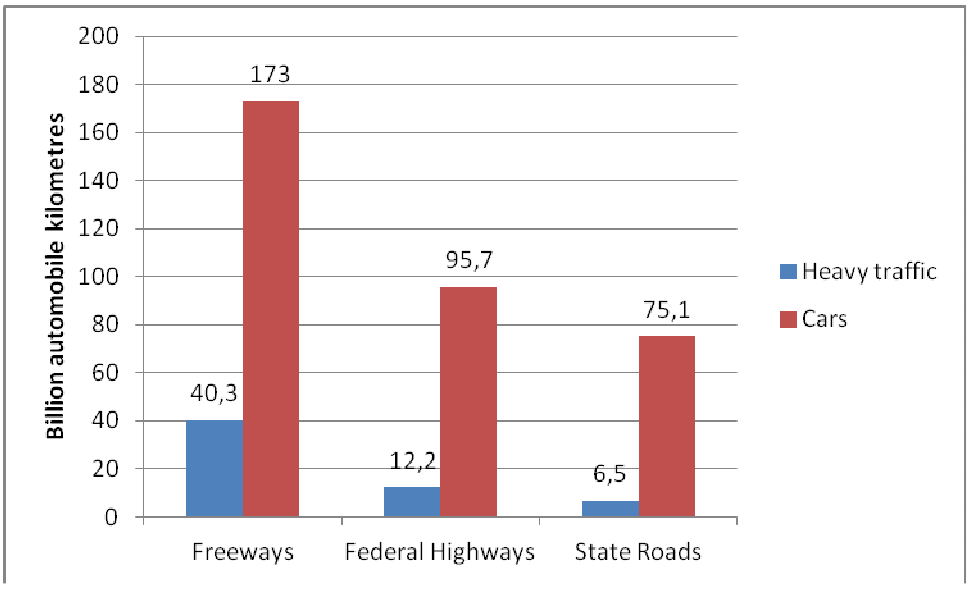


Figure 3.3 Mileage in Germany (Kathmann 2007, p. 11)

The part of heavy traffic especially on motorways is notably big, 213.3 billion automobile kilometers, which is 4.9 % bigger than in year 2000.

3.3 Summary

The AADT is notably higher in Germany than in Finland. On the motorways the AADT in Mecklenburg-Vorpommern, where the AADT is the smallest in the whole Germany, is bigger than on the busiest motorways in Uusimaa.

The big traffic volume leads to big mileage, which does not only strain the road surface and structure but also requires more from the safety issues of the road maintenance measures. The difference between Finland and Germany is big, because the total mileage in Germany is over 10 times higher than in Finland. The part of heavy traffic is relatively bigger in Germany, which also has effects on the things mentioned before.

4 CLIMATIC CONDITIONS

Climate conditions strongly influence the strategy of road maintenance in Finland and Germany. There are two identified Climatic Regions within Finland (Cold Maritime climate and Northern Climate) and four in Germany (Cold Maritime climate, Central-European climate, Mountain climate and Continental climate). The Climatic Regions are characterized in the following way.

Cold Maritime climate

- Relatively little snow
- Temperature changes
- Frequent snowdrift

Northern climate

- Very cold
- Snow

Central European climate

- Minimum temperature often near 0 ℃
- Relatively little snow
- Fog

Mountain climate

- Great fluctuations
- Low temperatures
- Much snow
- Strong winds

Continental climate

- Often very cold
- Long snowfall periods
- Relatively dry
- Relatively stable weather over longer periods

- Strong winds on some days
- Problems of snowdrift

In Finland the Northern climate is dominant and in Germany both Central-European and continental climate are dominant. (Cost 344 2002).

4.1 Finland

Conditions differ in the various parts of the country. In the coastal areas, where the climate is closer to a marine climate, weather and driving conditions vary greatly and slippery conditions develop easily. In the country's eastern and northern parts, the weather resembles a continental climate and is clearly colder. (Snow & Ice Databook 2010, p. 81).

The average temperature during the six winter months in Southern Finland is about -2 ℃ and in the North around -8 ℃ (Figure 4 .1).

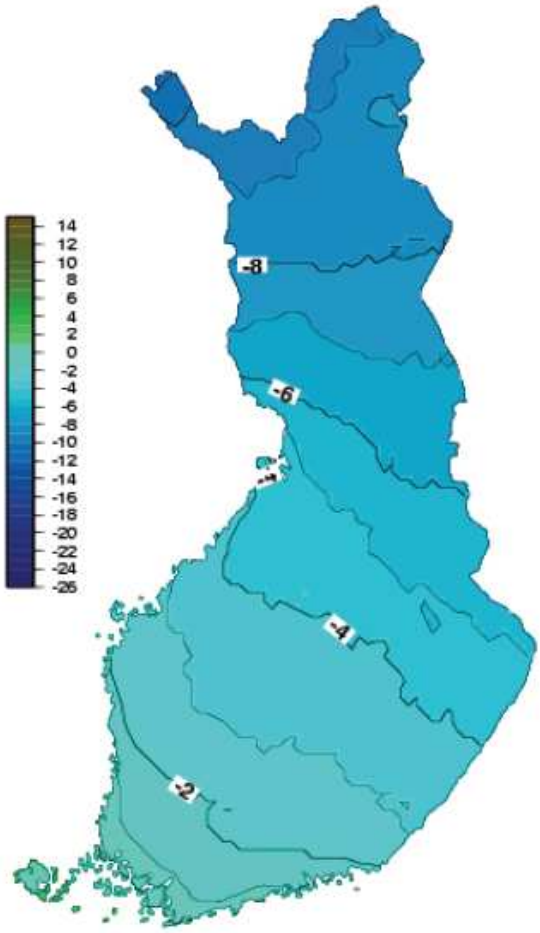


Figure 4.1 The mean annual winter temperature (℃) during 1971-2000 (Snow & Ice Databook 2010, p. 81)

Permanent snow falls usually in October or November in the North and in December in the South. The long-term average snowfall converted to millimeter of water varies from 120 to 220 millimeters in different parts of Finland (Figure 4.2). This amount of snow accumulates throughout the winter season, mainly as snowfalls under 10 millimeters. The annual rainfall is less than 600 millimeters in the North and 600-700 millimeters in the South. (Snow & Ice Databook 2010, p. 82).

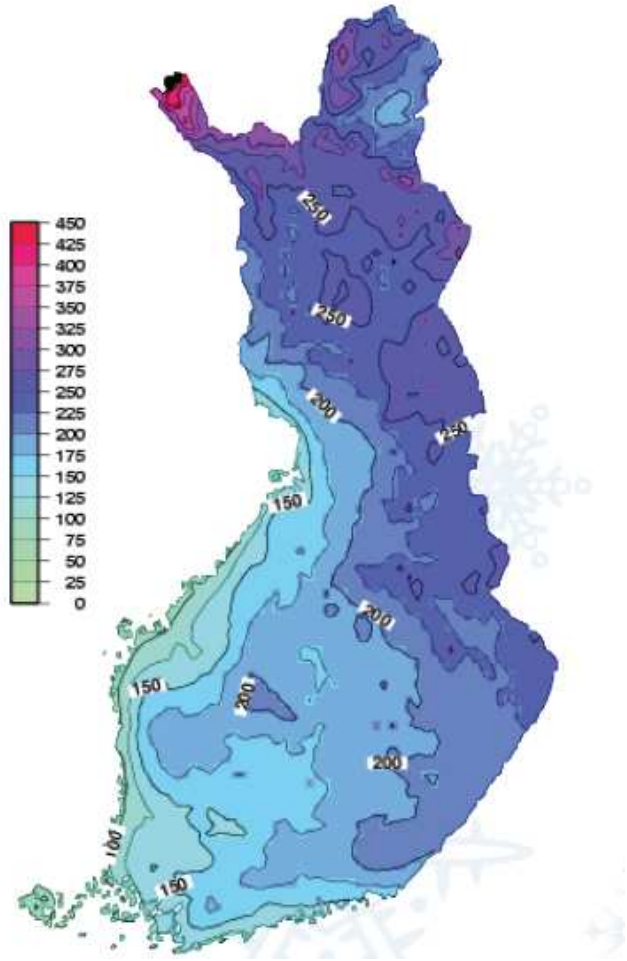


Figure 4.2 The mean annual snowfall (mm) during 1971-2000 (Snow & Ice Databook 2010, p. 82)

There is a costal climate on the southern and western parts of Finland and northern part the climate is more continental. The Baltic Sea and especially the Gulf Stream are making the climate warmer. Weather conditions can quickly chance in wintertime. This is why the de-icing is the main concern in coastal area and snow removal in northern parts. (Snow & Ice Databook 2010, p. 82).

There is snow in Lapland averagely even 62 % of a year. On the other hand, the southern Finland, where most of the traffic takes place has snow only 75–100 days in a year which is 20–27 % of a year (Finnish Meteorological Institute). Differences between different areas in Finland are huge, but snow still has effects on road maintenance widely in the whole country.

Snow is usually thickest in the middle of March, in Lapland often as late as early April. The average snow depth in March in southern Finland is 10- 40 cm, in

middle Finland 30 – 75 cm and in Lapland from 75 cm to over one meter. Latest in April the snow cover starts to melt fast in Lapland too. (Finnish Meteorological Institute).

4.2 Germany

Germany has a moderate climate, often weather changes are characteristic. From the low lands in the northwest to southeastern regions there is a gradual transition from maritime to continental climate. Mostly western winds and precipitation during the whole year are characteristic. Typical are frequent cold (continental) winds and snowstorms, from eastern European in southeastern Germany. In the northern lowland the yearly precipitation amounts to 500 mm to 700 mm in lower mountain ranges, in the middle part of Germany between 700 mm and 1 500 mm and in the south, close to alpine region up to 2 000 mm. (Snow & Ice Databook 2010, p. 103).

The daily and yearly temperature variations are not extreme, except in southeastern Germany and in the alpine region. Figure 4.2 shows the average daily minimum temperatures and precipitation during the main winter months.

Meteorological Stations (close to motorways) (m above sea level)		Meteorological Data (Average d-30 years) - Main Winter Months -									
		Average daily minimum temperatures [° C]				Average precipitation[mm]					
		Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	Total	Total year
1	Kiel (17 m)	- 0.3	- 2.1	- 1.8	0.4	74	65	40	54	233	777
2	Schwerin (59 m)	- 0.9	- 2.6	- 2.1	0.3	55	46	33	42	176	620
3	Hannover (53 m)	- 0.7	- 2.2	- 2.0	0.3	60	52	37	48	197	665
4	Berlin (48 m)	- 1.0	- 2.7	- 2.1	0.7	53	43	34	37	167	584
5	Bonn (62 m)	1.0	0.0	0.5	2.6	52	47	37	46	182	678
6	Erfurt (312 m)	- 2.2	- 3.6	- 3.4	- 0.5	30	25	26	36	117	492
7	Frankfurt (112 m)	- 1.0	- 2.1	- 1.6	0.9	54	44	40	51	189	658
8	Hof (474 m)	- 3.3	- 5.0	- 4.5	- 1.8	63	53	44	47	207	708
9	Stuttgart (373 m)	- 2.2	- 3.3	- 2.4	0.3	48	44	42	44	178	719
10	München (527 m)	- 3.7	- 5.1	- 4.0	- 0.8	60	53	52	56	221	967
11	Villingen – Schwenningen (720 m)	- 3.5	- 5.0	- 4.5	- 2.5	85	77	74	68	304	915
12	Kempten (705 m)	- 5.1	- 6.2	- 5.0	- 1.9	90	83	78	79	330	1,273
13	Bad Reichenhall (455m)	- 4.0	- 6.5	- 4.5	- 1.0	128	125	110	120	438	1,665
14	Garmisch-Partenkirchen (719 m)	- 5.7	- 6.5	- 5.1	- 2.3	92	85	77	96	340	1,364

Figure 4.3 The average daily minimum temperatures and precipitation during the winter months in different cities close to motorways. (Snow & Ice Databook 2010, p. 103).

The figure shows that the coldest month is January, when the minimum temperature is below 0 ℃ almost everywhere in Germany . In the alpine region it is colder compared to lowlands because of the altitude.

Typical for the German climate is the frequent change of temperature around 0℃ with freezing and thawing periods following eac h other. This creates many problems for winter maintenance. (Snow & Ice Databook 2010, p. 103).

There is snowfall in larger extent only in mountainous regions and the surrounding areas. Bavaria, the most southern State including the north edge of the Alps therefore is the most “snowy” region in Germany with winter maintenance from November to April, whereas in other parts of Germany there is a shorter winter period. But even in Bavaria there are great differences concerning the amount of snowfall in different parts of the state (Figure 4.3)

State of Bavaria	Annual cumulative snowfall (measure at motorway maintenance stations)	
	average of the last winter periods	Maximum: Winter 2005/06
Front of alpine region	440 cm	1,030 cm
Lower mountain regions	210 cm	645 cm
Lower areas, river valleys	50 cm	125 cm

Figure 4.4 Annual cumulative snowfall in Bavaria (Snow & Ice Databook 2010, p. 104)

Large parts of central and northern Germany receive the same amount of snow as the lower areas and river valleys in southern Germany. (Snow & Ice Databook 2010, p. 104).

Other typical features of the climate are the great variation in the severity of consecutive winters, in relation to temperature and amount of snowfall. The

main problems for the winter maintenance management are the often temperature changing around 0 ℃ or short heavy snowfalls. . (Snow & Ice Databook 2010, p. 104).

In most parts of Germany the winter is not as hard as in Finland but there are still many days of snow cover in Germany too, which are illustrated in figure 4.3. The regional differences are much smaller in Germany than in Finland excluding the alp region and some areas in Black Forest. (Rachner 2000).

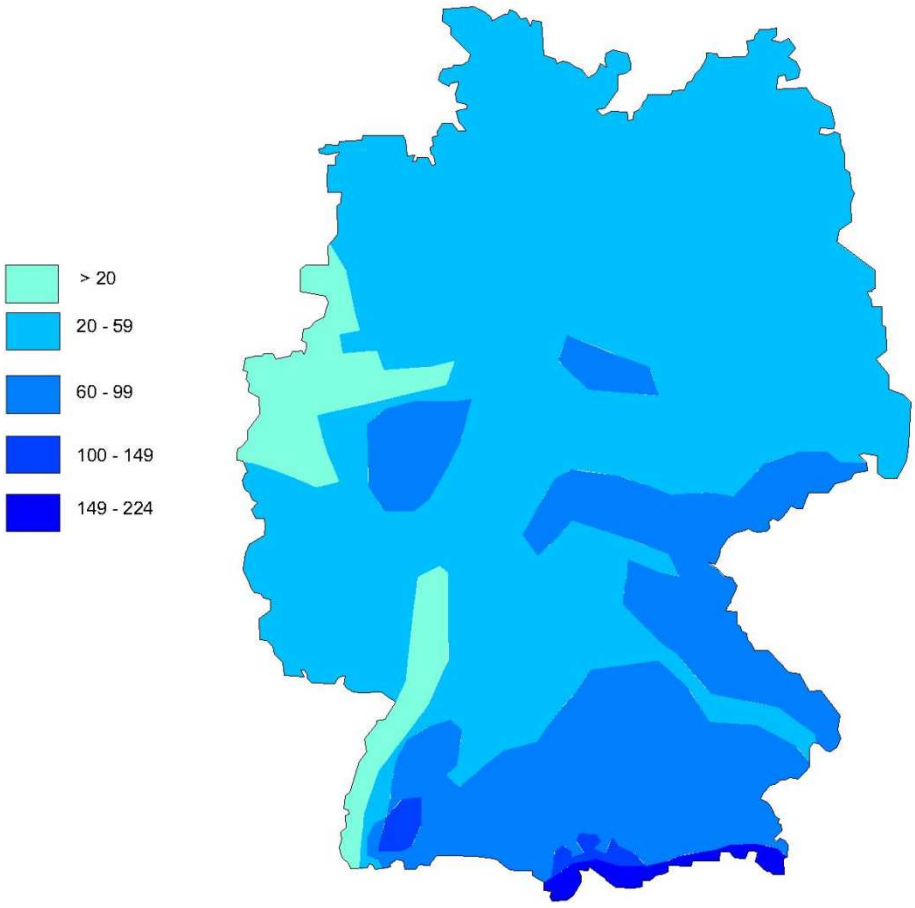


Figure 4.5 The number of snow covered days in 1961-1990 (Rachner 2000)

In the largest part of Germany, snow covers ground averagely for 20 – 59 days a year. Less than 20 days of snow cover is located at the Ruhr area and near the river Rhine. The snow cover is usually thickest during 11.1 – 10.2 in most of the country excluding the Alps and few other high located areas. In the whole Germany there have been approximately 60 – 70 days with snowing each year in 1901 – 1991. (Rachner 2000).

4.3 Summary

Winter in Finland is much stronger than in Germany but there are needs for the winter maintenance in Germany, too, due to the winter months when the average daily minimum temperatures are below 0 ℃ in al most every region in Germany.

Periods of strong freeze help to prevent slipperness in Finland while in Germany the temperature is often around 0 ℃ during the winter months, which is avery difficult temperature for the road maintenance.

The annual snowfalls in alpine regions are even bigger than the heaviest mean annual snowfalls in Finland. But it is notable that these heavy snowfalls occur only in mountainous regions, while in Finland thick snow covers large part of the country. Also the number of snow covered days is higher in Finland.

5 ORGANIZATIONS IN THE FIELD OF ROAD MAINTENANCE

5.1 Finland

History

In December 1799 King Gustav IV Adolf of Sweden issued a proclamation concerning the foundation of Finnish Transport Agency's early predecessor, the Royal Finnish Committee for the Cleaning of Water Rapids. The Committee focused on clearing waterways, but it also laid the foundation for the nationalization of road and water construction. (Finnish Transport Agency).

The agency's name and tasks have undergone many changes. Waterways were finally removed from the agency's mandate in 1990, and the administrative and production tasks of the National Board of Public Roads were split from the beginning of 1998. The name and concept of the National Board were abandoned in early of 2001, and two independent organizations were established: the Finnish Road Administration and the Finnish Road Enterprise, which is a state owned enterprise. Finnish Road Administration continued as the road maintenance authority and Finnish Road Enterprise as a contractor, competing with other enterprises on the business. (Finnish Transport Agency).

Current situation

In 1.1.2010 a new national board, Finnish Transport Agency, was established after the Road Administration, the Rail Administration and the Maritime Administration were united as a part of Centre for Economic Development, Transport and the Environment. (Ministry of Transport and Communications)

The Finnish Transport Agency is responsible for the management of the countrywide public road network. The Finnish Transport Agency operates through 15 regional Centres for Economic Development, Transport and the Environment and they have replaced the Finnish Road Administration as a road manager and a client of the road maintenance. They order the maintenance as area maintenance contracts from contractors. (Centre for Economic, Development, Transport and the Environment)

5.2 Germany

History

In 1998 The Federal Ministry of Transport, Building and Urban Development was created by merger of the former Ministry of Transport and the Federal Ministry of Regional Planning, Building and Urban Development. They were both established in 1949. Originally the new ministry was named Federal Ministry of Transport until it adopted its current name in 2005. (Federal Ministry of Transport, Building and Urban development).

Current situation

Under The Federal Ministry of Transport, Building and Urban Development operate the states which are in charge of planning, construction and maintenance for motorways, federal highways and state roads. The Federal ministry has the right of legal technical supervision for the motorways. This pattern is shown in figure 5.1. In every state operate administrative bodies of motorways and under them motorway administrative authorities (Autobahnmeistereien). There are also administrative bodies of Federal-, State-, and District roads and under them administrative authorities of the roads (Strassenmeistereien). (Beckers, 2005)

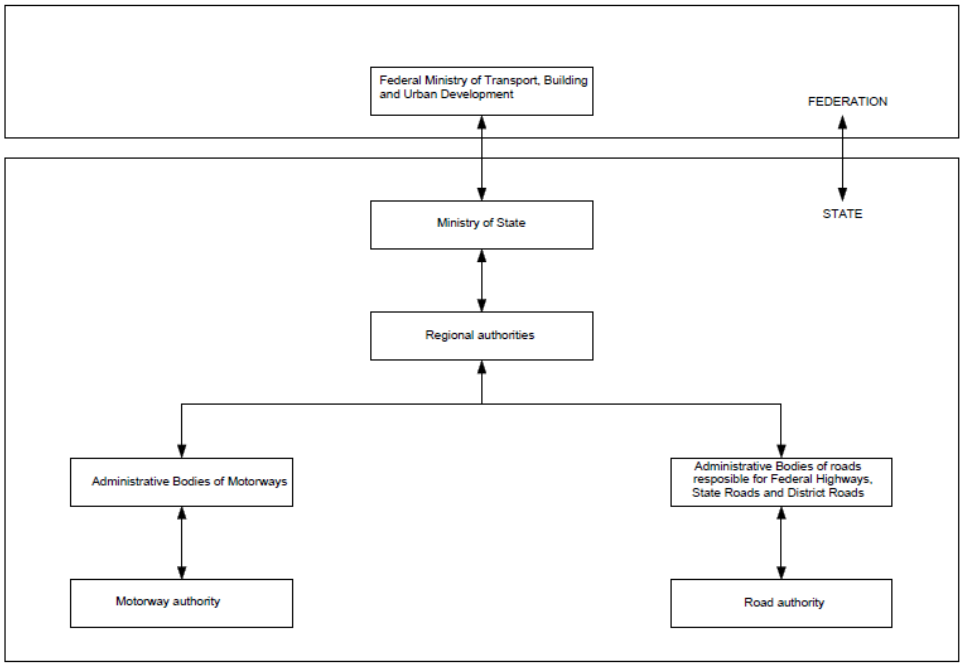


Figure 5.1 Pattern structure of the road maintenance authorities (Beckers 2005, p. 51)

In 2010 there were 185 motorway administrative authorities and 583 road administrative authorities in Germany. The road maintenance is performed by these authorities (Der Elsner , p. 1095).

The states manage the orders of federation in motorways and federal state highways. They manage their own state roads as well and also in some states district roads. They are responsible for the organization of their own Road Administration and therefore there are also organizational differences between the states. (Der Elsner)

6 THE IMPLEMENTATION OF ROAD MAINTENANCE IN FINLAND

Since the beginning of 2005 all the products and services concerning the road management have been put out to tender. The competition opened gradually during 2001-2004. The form is area-wide maintenance contract in which the maintenance contractor is responsible for the year-round maintenance of the roads belonging to area. The contractors for each region are chosen on the

grounds of a price and quality competition. The contracts are awarded by Centres of Economic Development, Transport and the Environment. (Finnish Transport Agency)

6.1 Contracts

The daily maintenance of highways is implemented in 81 different maintenance areas which are illustrated in figure 6.1. The duration of the contracts are from 5 to 7 years in general and each year 10-15 contracts are put out to tender. (Finnish Transport Agency)

The road maintenance measures are winter maintenance, maintenance of gravel roads, maintenance of the traffic environment, maintenance of the paved roads and maintenance of the bridges. They ensure the traffic ability of the current road network and maintain its current condition. Every road must be surveyed during winter period (1.10 – 31.5) every week and summer period every second week by a qualified person. (Finnish Transport Agency)

Each contractor has the overall responsibility for the maintenance of the roads included in the contract area allocated to them, taking care of the supervision of the project, the performance of the maintenance duties, the assurance of quality and the necessary purchases. (Snow & Ice Databook 2010)

6.1.1 Winter maintenance

The task for the winter maintenance is to secure the good condition of the highways through the winter. Because all the highways cannot be maintained immediately, they are divided to different classifications depending on the significance of the road. The main tasks for winter maintenance are ploughing, deicing, cleaning the traffic signs from snow and doing precise maintenance for problematic targets. (Finnish Transport Agency)

6.1.2 Maintenance of the gravel roads

The endurance of the gravel roads against traffic load and weather conditions is smaller than paved road network. The biggest problem for gravel roads is the rasputitsa which can be partly prevented by maintenance. The surface of the road is described estimating flatness, solidness and dustiness of the road. (Finnish Transport Agency)

6.1.3 Maintenance of the traffic environment

The tasks considering the traffic environment are to take care of comfortableness and safety of the road areas, resting areas and bus stops. Also sanitation of offside areas is part of the maintenance. Road safety is improved by green works on offside areas. This includes cutting and clearing the coppice. The good condition of traffic signs, guidance signs and street lights are also tasks that improve traffic safety. (Finnish Transport Agency)

6.1.4 Maintenance of the paved roads

Maintenance of the paved roads aims to road safety, driving comfort and persistence of the road network. Mainly paved roads are maintained in contract areas by filling the emerged holes and stabilizing crazings. (Finnish Transport Agency)

6.1.5 Maintenance of the bridges

There were about 14 200 bridges on highways in 2010. The contractor is obligated to inspect all the bridges in contract area once in a year and report the possible problems to client. In addition all bridges must be washed 2 times in a year, at spring and autumn. (Finnish Transport Agency)

6.1.6 The maintenance areas

As mentioned before, there are 81 road maintenance areas in Finland. The length of road network varies from 500 kilometers to 2 000 kilometers on these areas .They are illustrated in the figure below as well as contractors of the areas 1.10.2011-30.9.2012. (Finnish Transport Agency)

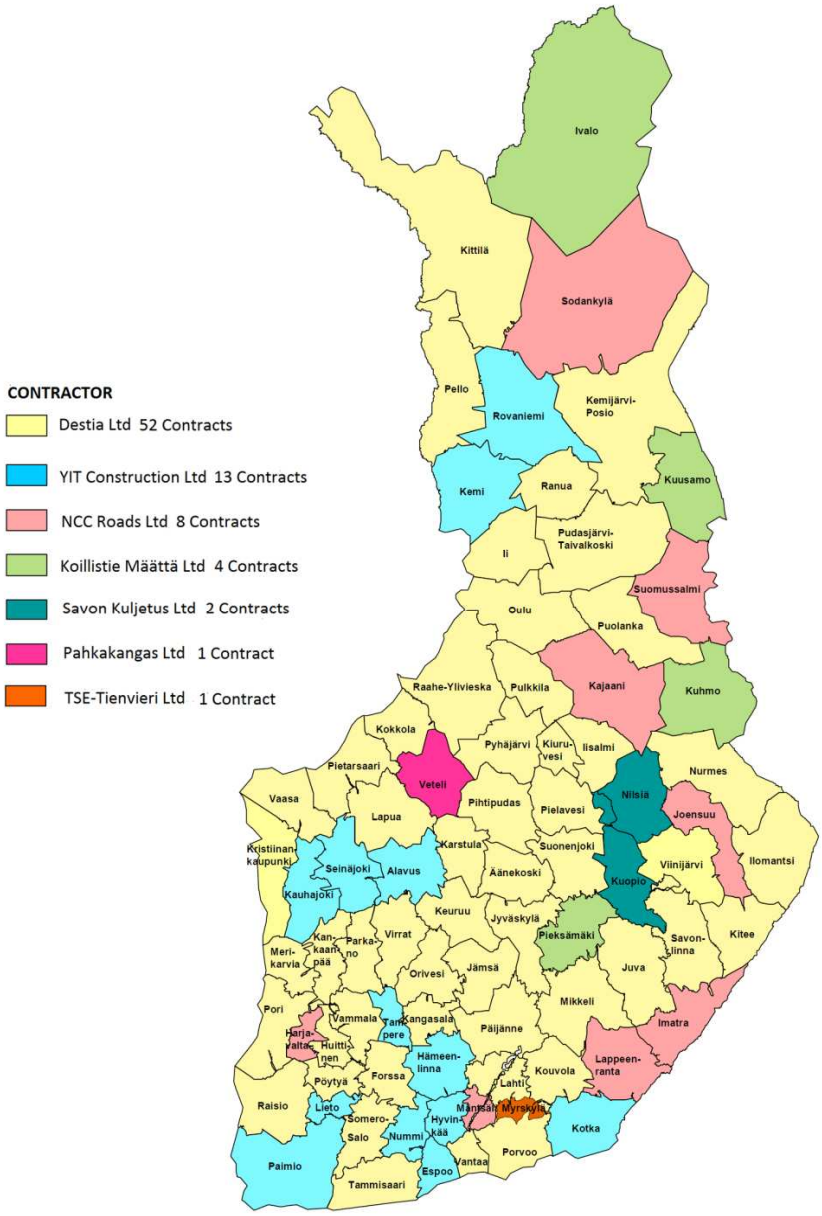


Figure 6.1 Road maintenance areas and contractors 1.10.2011-30.9.2012 (Finnish Transport Agency)

The former Finnish Road Enterprise, state owned Destia Ltd, is the biggest contractor with the share of 52 maintenance areas. The second biggest and the biggest private contractor is YIT Construction Ltd which has 13 maintenance areas, followed by NCC Roads Ltd with the share of 8 contracts. The rest of the contractors are smaller and more local operators.

The contracts are put out to tender after the principles of public purchases as an EU-purchase. Also foreign companies are allowed to offer but the offers must be done in Finnish. All documents are only available in Finnish. Enrollment for

the bidding of the contracts starts already at the November preceding year and ends in the middle of December same year. (Finnish Transport Agency 2010).

6.1.7 Requirements for the contractors

The contracts are divided into three different classes based on demanding of the contracts. The distribution is based generally on the road network of each maintenance area. In addition, for example experimenting new methods, may affect classification. (Finnish Transport Agency 2010).

A contractor has to provide a tentative plan for quality and operation which will be evaluated. The maximum amount of points is 1 000. The exact classes and minimum requirements of points are the following:

Basic contracts	400 points
Demanding contracts	450 points
Very demanding contracts	500 points

Between contractors whose plan is accepted, takes place a tender, in which the cheapest offer wins. (Finnish Transport Agency 2010).

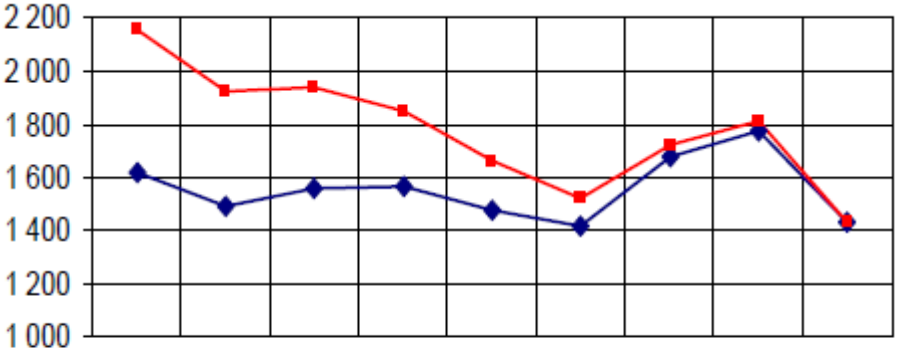
For the companies, a requirement for an annual turnover is set in every contract. Usually in basic contracts the turnover is required to be as big as the annual cost estimate of the contract, demanding contracts 1,5 times bigger and very demanding contracts 2 times bigger than the annual cost estimate. (Finnish Transport Agency 2010).

In every contract the contractor is required to have the RALA Certification of Competence or SFS-EN ISO 9001 quality certificate. There are also other demands for the company, such as experience of supervisors of the company and experience for the similar works as a main contractor. Also it is required that the company must not have tax debts or any similar debts whatsoever. These requirements are different depending on the demanding of the contract. (Finnish Transport Agency 2010).

6.2 The cost of the road maintenance

The competition in road maintenance is very strict in Finland. The costs are determined by the offers; therefore the competition determines the total cost of the

road maintenance, excluding the extra works such as for example urgent measures and additional works. Figure 5.2 shows the prices of the winning offers of the maintenance areas from 2003 to 2011. There are 2 graphs in the figure; one is the real value and the other one index value based on year 2011. (Finnish Transport Agency 2011).



	2003	2004	2005	2006	2007	2008	2009	2010	2011
€/km	1 617,08	1 491,04	1 562,72	1 565,69	1 478,74	1 418,51	1 677,81	1 772,08	1 428,62
€/km ind 144,3	2 158,60	1 926,20	1 935,62	1 848,85	1 667,05	1 521,87	1 719,52	1 816,13	1 428,62

Figure 6.2 The prices of contracts by the offers in 2003-2011 (Finnish Transport Agency 2011)

The figure shows that from year 2003 prices have dropped down. The value calculated with index in 2003 is almost 700 €/km bigger than the value in 2011. Anyway the figure excludes the maintenance areas of Espoo and Vantaa from years 2004 and 2009 which would make the average price bigger for these years. Both of these areas are located on Uusimaa with the biggest traffic amount and most of the highways in the whole Finland. However, including these two areas would not affect the price in year 2011.

The cost distribution between different measures of maintenance is illustrated in figure 6.3. It shows that the biggest part of the costs is comprised in winter maintenance which is inevitable considering the weather conditions in Finland.

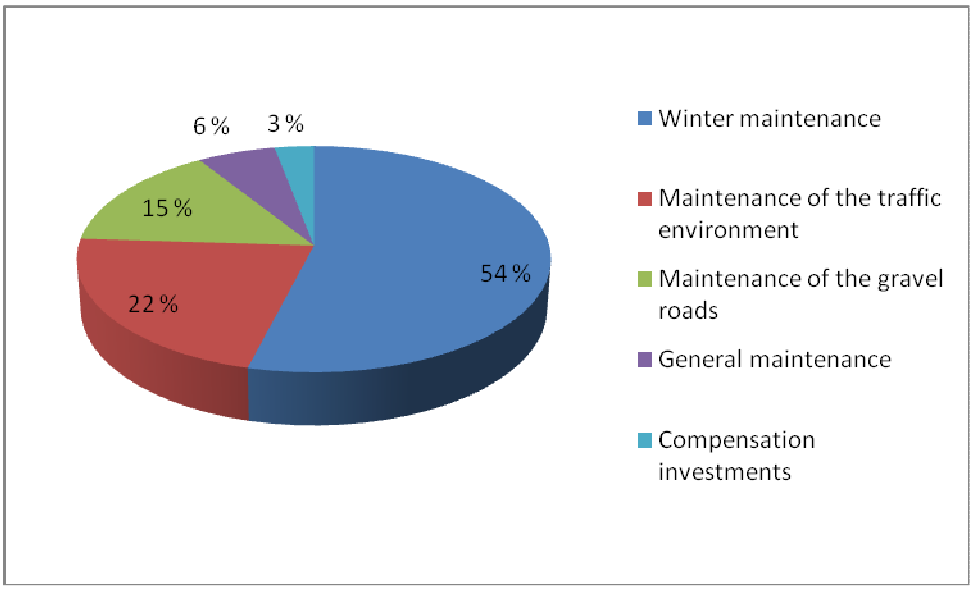


Figure 6.3. The distribution of the costs in road maintenance. (Finnish Transport Agency 2011)

The share of cost into gravel roads is remarkably big considering their traffic loads and their low significance. This also gives a major difference compared to Germany, which has no gravel roads at all.

7 THE IMPLEMENTATION OF ROAD MAINTENANCE IN GERMANY

In most parts of Germany road maintenance is not put out to tender but is performed and supervised by the motorway and road administrative authorities. The only state in Germany where the maintenance of federal highways, state roads and district roads is completely privatized is Thuringia (Elsner 2011, pp. 1109). In 1996 “Thüringer Strassenwartungs- und Instandhaltungsgesellschaft”, TSI, was formed as a 100 % state-owned organization. Since 2002 it has been 100% private-owned. It is meanwhile both a public administration and an enterprise, which makes competition available for the private sector. (TSI).

According to Der Elsner (2011 p. 1107), there have been the following efforts to use different implementation models to make road maintenance more cost-efficient;

- Public Private Partnership, which is mainly used only in municipal field.

- Munipalization of the road maintenance, which has been implemented as part of the administrative reform in Baden-Württemberg in 2005 and in Saxony in 2008.
- Privatization of the road administrative authorities, where the pilot projects took part in Lower Saxony in 2004-2007 and in Hesse 2007-2010.

The pilot project in Hesse started in the district of Darmstadt-Dieburg which comprises 103 kilometers of federal highways, 151 kilometers of state roads and 97 kilometers of district roads. Following the formal tender process were the operations of regarding road administrative authority, from 31st of October 2007 to 1st of September 2010, transferred to TSI. The benefits of this pilot project were found minor, so the scheme was terminated after three years of operation. (Hessen).

Since 2009, so-called “mini road administrative authorities” have been successfully tested nationwide. This model enables the optimal economical ratio between the staff of the road administrative authorities and the subcontractors. (Elsner 2011, p. 1108).

7.1 Road maintenance areas

Averagely one motorway administrative authority has a responsibility to maintain the following objects on its area:

70 km	length of motorway network
35 km	of one-lane and two-lane ramps
10	interfaces
1	motorway interchange
2	tanking and resting areas
4	WCs
165	bridges
270 km	of railings
1815	traffic signs
146 ha	of green areas

The areas are relatively small and past experiences of the road administrative authorities show that in economic sense the maintenance area should include at least 300 km length of road network. (Der Elsner 2011).

Every road administrative authority has averagely 275 kilometers of road network on its area. Each administrative authority has approximately 25 employees which corresponds one employee in every 10 kilometers of a road network. On motorways, the number of road caretakers is dependent on the length of the road network and the number of lanes of roads. (Der Elsner 2011). According to Lorenz it comprises the following way:

70 km	2 lanes	19 employees
	3 lanes	23 employees
105 km	2 lanes	25 employees
	3 lanes	31 employees
140 km	2 lanes	31 employees
	3 lanes	39 employees

In addition there are craftsmen and office workers depending on the length of the road network.

One road administrative authority employs approximately 10 – 20 road caretakers, 1 – 1,5 craftsmen and 3 – 5 employees in office. (Der Elsner 2011)

Meanwhile, there have been good experiences of so called “mixed authorities”. They operate both on motorways and federal and state roads. The number of the road maintenance depots can therefore be reduced and capacity utilization is increased. (Lorenz 2006)

7.2 Road maintenance measures

The traffic and environmental impact claims a lot from road and its components. Timely implemented care and maintenance of the road lengthen the lifespan of the road and guarantees safe traffic. The measures of road maintenance do not generally lead to the improvement of the substance of road infrastructure. The failure, however, reduces its capacity.(Der Elsner 2011).

Road maintenance measures are maintaining the routes, winter maintenance, road cleaning, green areas care, environment maintenance, structure maintenance, environmental consideration, securing short-term scheduled work, and traffic monitoring to avoid congestions.(Der Elsner 2011).

7.2.1 Maintaining the routes

The most important task for the road maintenance is to ensure safe traffic ability and accomplish it in an economic way. Because of this route maintaining is a core task of the road maintenance which is the result of the road-safety obligations. It consists of regular surveillance of the roads combined to up keeping and maintenance operations. (Der Elsner 2011).

According to Lorenz (2006) it also comprises repairing minor damages and removing or covering hazardous objects. These tasks must be done at least once in every week. If necessary, they have to be repeated more often. Central facilities, such as emergency telephones and escape routes on noise barriers, must be checked once in every month.

7.2.2 Winter maintenance

Because of the slipperness and snow, the traffic safety and the abilities of the roads are considerably limited. The winter maintenance must therefore restore traffic safety and effective abilities.(Der Elsner 2011).

7.2.3 Road cleaning

The roads, their adjacent areas and all traffic facilities have to be cleaned to ensure the traffic safety. The cleaning work must be fulfilled by the interests of general conservation, conservation of the countryside, hygiene and obeying the rules and regulations. The road cleaning outside the city areas belongs to road authority. (Der Elsner 2011).

7.2.4 Green areas maintenance

Green areas care as part of the road maintenance improves traffic safety and protects the road structure from erosion. It also prevents forming of snowdrifts and visual covers.(Der Elsner 2011).

According to Lorenz (2006) the lawns are divided into two different functional care areas:

- Intensive care area, which has to be cut two or three times in a year (road shoulders, drainage trays, middle lanes, fields of view in interfaces and inner curves)
- Extensive care area, which must be mowed once in a year. (resting areas on motorways and slopes). The height of cut must not be more than 8 cm.

7.2.5 Environmental maintenance

The environmental maintenance comprises small-scale repair works of the road equipment. The operations in environmental maintenance are implemented in order of importance by the following criteria:

- Avoidance of any danger for the road user, operators or third side during the repair.
- To make sure of the traffic safety with the condition of road equipment.
- Endurance of the equipment.

The road equipment includes the following objects:

- traffic signs
- traffic lights
- protective barriers
- delineators
- road markings
- boundary stones
- lighting devices
- animal-tight fences
- noise barriers
- traffic mirrors

The maintenance of the lighting devices will be transferred to companies in the future. (Der Elsner 2011).

7.2.6 Structure maintenance

Traffic safety and existing structures require constant monitoring and inspections which have to be performed by a classified person (Der Elsner 2011)

DIN 1076 defines these structures in following way:

Bridges are overpasses of a traffic route over natural obstacles or other traffic routes whose clear width between the abutments is 2 meters or more. According to Lorenz (2006) observations have to be performed constantly and inspections once in a year.

Road sign bridges are supporting structures on which the traffic signs are attached above the road area. They also include corresponding support structures with unilateral or bilateral projections that reach over the road area entirely or partly.

Tunnels are road traffic serving structures which are under the earth's surface or water surface. They are produced as enclosed construction or open construction with the minimum length of 80 meters. Tunnels also include ancillary systems that are required for maintenance. These systems are integrated to tunnel structures. Furthermore the following structures are included in tunnels:

- partly covered traffic structure above or below ground level, for example grid ceiling
- enclosure of the street above ground level, for example noise barrier as a half covered framework
- crossroad-structure with other traffic routes
- protection structures, for example avalanche shelter

Trough structures are retaining structures and ground water tanks that work as retaining walls which are located on underground level.

Retaining structures perform retaining function towards the soil, the structure of road or water and have visible structural height of 2 meters or more.

Noise barrier structures perform protective function against noise caused by traffic and have visible structural height of 2 meters or more.

7.2.7 Environmental consideration

The road maintenance measures have numerous points of contact with the regulations of Environmental law. Street and parking area cleaning causes different wastes which have to be disposed in accordance with Environmental law. In

winter maintenance the grit must be used effectively to avoid unnecessary materials ending up to environment. There are also technical and operational introduction considering the storage of the gritting agents for winter maintenance. (Der Elsner 2011)

7.2.8 Securing short-term scheduled work

The working positions require great efforts because there are more than 100 000 short time working positions every year. The risk for the accidents is over 13 times bigger for the employees in road maintenance than for industrial workers. (Der Elsner 2011)

According to the research in the University of Karlsruhe, there is the following information from the accidents in working positions on motorways during years 1997 - 2005:

- 951 accidents
- 7 deaths, 42 serious and 120 minor injuries
- approximately 2/3 of accidents are caused by lorries
- almost 2/3 of the accidents took place on stationary working positions
- 75 % of injured employees were injured during impact of a vehicle
- whiplash-injuries have a big part of all injuries

As the result of this data, recommendations for action to avoid accidents in short time working positions have been developed. (Der Elsner 2011)

7.2.9 Traffic monitoring to avoid congestions

The implementation of the road maintenance leads to capacity decrease of highly strained motorways and hereby to traffic obstructions. The increasing traffic density with the simultaneous rising amount of the complex repairs lead to intensified problems. There are operational and organizational or traffic technical possibilities to improve this problem:

Operational and organizational possibilities

- examination of road maintenance to reduce the work time on the traffic areas
- examination of the work methods

- coordination of different works
- relocating the work to night time

Traffic technical possibilities

- information of construction sites and congestions for road users
- consideration of the requirements for the operation of the traffic management system
- co-use of additional lanes for the 2-lane system (Der Elsner 2011)

7.3 The cost of road maintenance

According to Der Elsner (2011) in year 2010 the total amount spent to road maintenance per kilometers including personnel, equipment and material costs in Germany was divided in the following way;

Motorways	33 740 €/km
Federal Highways	11 180 €/km
State Roads	6 000 – 7 000 €/km
District Roads	3 500 – 6 500 €/km

The share of the motorways is notably high but it can be explained by the high number of lanes on certain motorways, likewise the high traffic load of them. Overall the cost is remarkably higher than in Finland. Figure 7.1 shows the development of the costs in years 2004 – 2010. Unlike in Finland the costs have risen every year on motorways and federal highways.

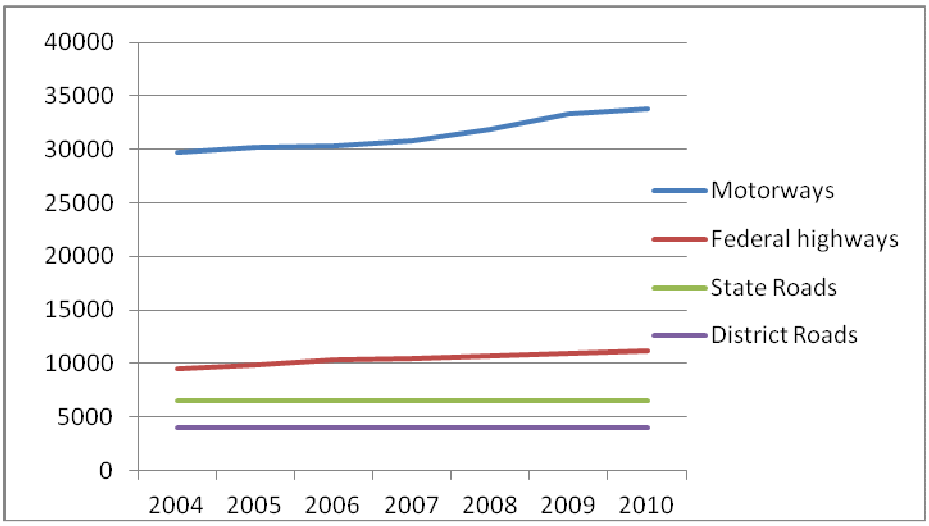


Figure 7.1 The development of the costs in years 2004-2010 in road maintenance €/km (Der Elsner 2011, p. 1095)

The values of state roads and district roads are average values from those roads of all states; therefore there are no chances perceptible. The figure also tells that the costs on motorways have risen relatively more than on federal highways, especially during 2007 - 2009.

Table 7.1 illustrates the shares of the cost by tasks of maintenance in North Rhine Westphalia and table 7.2 in Bavaria. These are the states in Germany with the most amounts of motorways and federal state roads. They are also in different areas in Germany and they have different climatic conditions compared to each other.

Table 7.1 The cost by tasks of road maintenance in North Rhine Westphalia (Der Elsner 2011, p. 1006)

Task	**Motorways**	**Federal State Highways**	**State Roads**
Urgent operations for the structure of road	4 %	6 %	10 %
Green works	18 %	24 %	21 %
Maintenance of environment	12 %	22 %	23 %
Cleaning of roads	19 %	11 %	10 %
Winter maintenance	18 %	21 %	22 %
Route maintenance measures	29 %	16 %	14 %

.

The route maintenance measures also include removal of damages. The table shows that the biggest difference between different classes of roads is in route

maintenance tasks. This can be explained by higher traffic load and higher speeds which is the main reason why accidents happen more.

Table 7.2 The cost by tasks of road maintenance in Bavaria (STMI)

Task	Motorways	Federal State Highways and State Roads
Urgent operations for the structure of road	5 %	11 %
Green works	16 %	19 %
Maintenance of environment	9 %	8 %
Cleaning of the roads	12 %	6 %
Winter maintenance	35 %	47 %
Route maintenance measures	23 %	9%

The share of winter maintenance in Bavaria is considerably large compared to North Rhine Westphalia. This is partly due to the average number of snow covered days in a year as shown in figure 4.3. In any other aspect, the shares between these two states are very similar, even compared to Finland.

8 WINTER MAINTENANCE

8.1 Finland

Winter maintenance includes clearing of the snow, evening the road surface and de-icing. It also includes plough marking, cleansing the traffic signs, lowering the snow banks, removal of snow and preventing harms caused by melting snow. The road network is divided into five different maintenance classes. In addition, class Ib has a corresponding maintenance class TIb for built-up areas. Table 8.1 shows the classes, the road lengths of them and the percentage share of traffic in 2009. (Finnish Transport Agency)

Table 8.1 The winter maintenance classes (Finnish Transport Agency)

Winter maintenance class	Length km	Share of traffic %
Is	3 194	40
I	3 758	17
Ib + TIb	10 377	22
II	19 916	14
III	40 916	6

It is shown in the table that the most demanding class, Is, includes least of road kilometers but even 40 % of all traffic. On the other hand, class III only includes 6 % of all traffic with the total length bigger than other classes put together.

Most of the Is-class roads are in Uusimaa, South West Finland and Pirkanmaa. Each class has a different level of service and quality standards. The level of service is mainly defined according to traffic volume, road functional class and regional climate. In addition, there are classes K1 and K2 for the pedestrian and bicycle paths. (Finnish Road Administration 2009a).

8.1.1 Snow clearing

The main priority for the winter maintenance is first to clear the snow away and then perform the measures of de-icing. The roads with heavy traffic volume are to be maintained first. The aim is that busy roads and pedestrian and bicycle paths would not have more than few centimeters of snow. After the snowfall has ended, the main roads must be cleaned from snow in a couple of hours and pedestrian and bicycle roads latest in four hours. On the roads of small traffic load the snow must be cleaned in six hours after the end of snowfall. Table 8.2 shows the requirements for snow clearing in different winter maintenance classes. (Finnish Road Administration 2009a).

Table 8.2 The requirements for snow clearing (Finnish Road Administration 2009, pp. 11)

Winter maintenance class	**Maximum snow depth during snowfall (cm)**		**Cycling time (h)**	
	Loose snow	Slush	Loose snow	Slush
Is	4	2	2.5	2
I	4	2	3	2.5
Ib and TIb	4	2	3	3
II	8	4	4	4
III	10	5	6	6

The requirements for the classes Is and I are much stricter than for the classes II and III. This reduces the cost of winter maintenance because more the half of the roads are in class III as mentioned before. If snowing continues after 22.00 pm, the pedestrian and bicycle paths must be ploughed before 6.00 or 7.00 am depending on maintenance class. (Finnish Road Administration 2009a).

8.1.2 Evenness of the road surface

The surface of the road must be even during the winter. Table 8.3 shows the requirements for the evenness for the roads with roughened surface of snow. (Finnish Road Administration 2009a).

Table 8.3 The biggest allowed unevenness in the winter maintenance classes (Finnish Road Administration 2009a, p. 13)

Winter maintenance class	Biggest allowed unevenness
Is	-
I	1
Ib	1,5
TIb	2
II	2
III	2

As can be noticed, class Is must not have roughened surface of snow. This means that the roads in this class must be kept bare during the winter.

8.1.3 De-icing

For the sake of traffic safety the fraction between tires and road surface must be big enough also during the winter. For the roads with low amount of traffic sanding is a sufficient measure but with busy roads with ice and snow on their surfaces it is difficult to maintain fraction big enough. The combined effect of traffic, snow and ice makes the road surface slippery and therefore the grit will not last on the road. In this situation it is reasonable to use the friction of the road and melt down the snow and ice by salting. (Finnish Road Administration 2006).

Measuring the friction is based on optical observation, notices during driving, description of the road conditions (Table 8.4) and measurement of the friction. (Finnish Road Administration 2009a).

Table 8.4 Description of the road conditions by the friction value (Finnish Road Administration 2009a, p. 14)

Friction	0.00-0.14	0.15-0.19	0.20-0.24	0.25-0.29	0.30-0.44	0.45-1.00
Road Surface Description	wet ice **very slippery**	icy **slippery**	tightly packed snow **satisfied**	rough packed ice and snow **good**	bare and wet **not slippery**	bare and dry **not slipperry**

The road surface is the most slippery when there is wet ice formed on it and slippery when it is icy. This usually occurs when the temperature is near 0℃. These conditions can be prevented by salting which is possible when the temperature is -4℃ or higher. During severe cold, sal ting is no longer possible and melting the road surface is not efficient. (Finnish Road Administration, 2006)

Due to the significant wastage, the use of dry salt is forbidden as a method of de-icing. Salt is applied either as a solution or moistened prior to spreading. Roads in classes Is and I are kept unfrozen throughout the winter, as a result of which slipperness of these roads has been prevented in advance, where-by less salt is required than in situations involving already formed layers on ice. (Ice & Snow Databook 2010, p. 86)

The annual amounts of used salt have been decreasing in long time frame and they have been under control even during hard winters. The consumption of salt in winter maintenance is around 80 000 tons which is illustrated in figure 8.1.

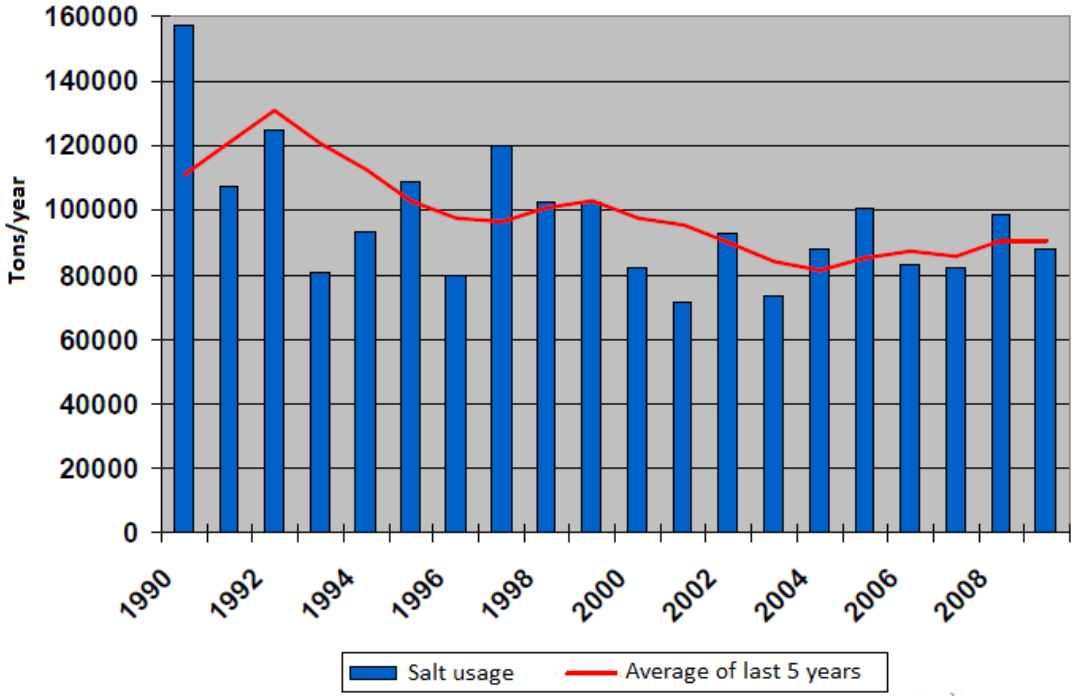


Figure 8.1 Salt consumption in years 1990-2009 (Finnish Road Administration 2009b, p. 2)

As showed in figure, the consumption of salt is rarely over 100 000 tons in winter. However, it can increase fairly over 100 000 tons during mild and rainy winters like in 1990, 1992 and 1998.

There are big differences between the winter maintenance classes in salt consumption which are shown in figure 8.2.

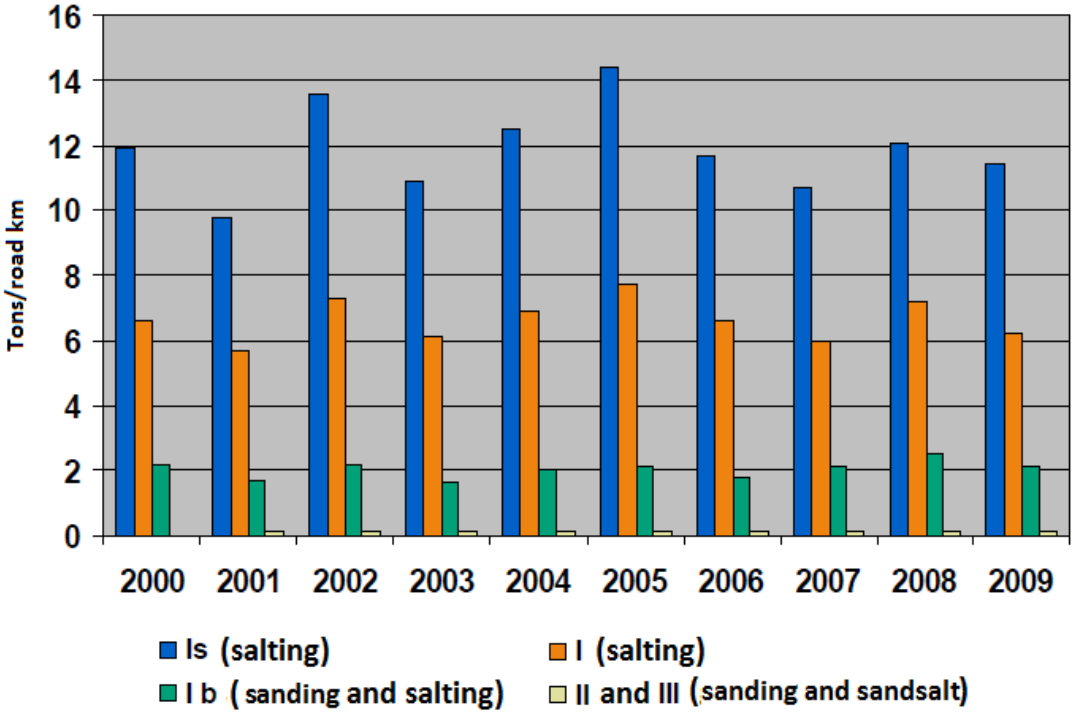


Figure 8.2 Salt consumption on the roads of different maintenance class (Finnish Road Administration 2009b, p. 3)

Salt is used in every maintenance class, but on classes II and III only as a part of sanding. Also the amounts on class I roads are much lower than on the roads of higher maintenance class. The length of most salted roads is around 6 900 kilometers (Is and I) with 57 % of the total traffic amount. In addition there are approximately 10 000 kilometers less salted roads (Ib), in which salting is limited to autumn and slipperness caused by mild weather. (Finnish Road Administration 2006).

Sanding is used as a primary de-icing method on the roads with hard ridge of snow and pedestrian and bicycle routes. Specific targets for sanding, such as curves, hills and intersections, are gritted when slipperness hampers their functioning. Line sanding is performed with whole the length of the road. Sanding

must be started immediately on the roads with roughened surface when problems occur. (Finnish Road Administration 2001).

Sand salt is used on the intersections of the main roads and other problematic areas. The combine effect of grit and salt breaks the ice membrane and humidity improves the attachment of grit on road. The sand salt is produced by mixing 15 kg of salt in one cubic meter of sand. The other way to produce sand salt is to moisten the grit with salt solution. (Finnish Road Administration 2001)

8.1.4 Costs

The winter maintenance costs are about 98 million euros. This indicates a cost approximately 1 200 - 1 300 euros/kilometer. Figure 8.3 shows the costs in different maintenance classes in 2007, when the total cost of winter maintenance was 93 million euros. (Ice & Snow Databook 2010, p. 85).

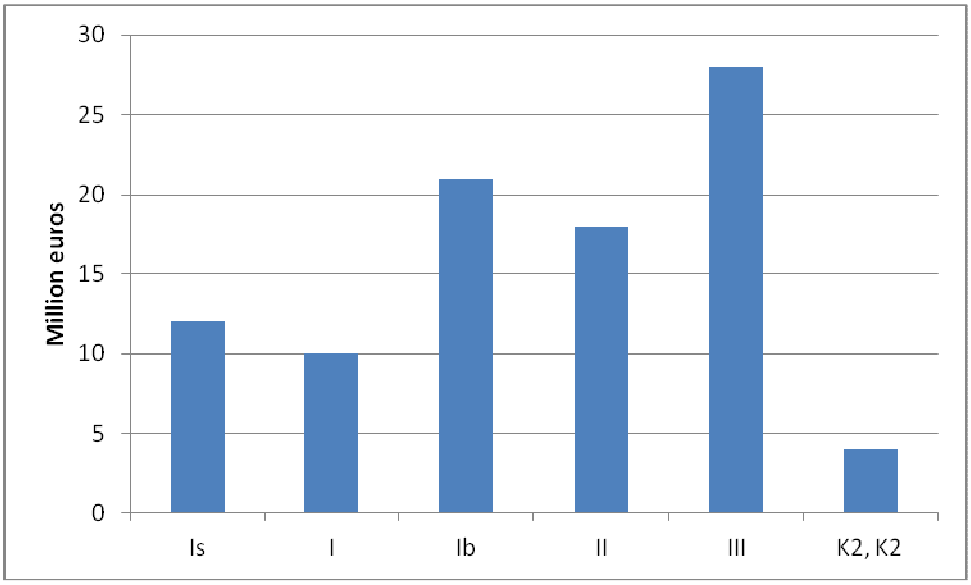


Figure 8.3 The cost of winter maintenance in different winter maintenance classes in 2007

The cost of the higher-level roads is notably big considering the total length of them, which tells that the winter maintenance on these roads is much more expensive than on lower-level roads. On class Is the cost was near 4 000 €/kilometer and class III 500-600 €/kilometer. Due to the large number of class III roads, even a small increase in the level of quality would cause significant additional costs.

8.2 Germany

The main tasks for winter maintenance in Germany are to maintain traffic safety, secure optimum conditions and sufficient capacity of the roads even during the winter months. (Elsner 2011, p. 1120)

The legal obligation to do winter maintenance results from a general duty out of the German Civil Code. It is reduced in the federal laws and the state laws and in the statutes of the cities. (Snow & Ice Databook 2010, p. 104)

Regulations about the requirements, organization and realization of winter maintenance are given in the Guidelines for Winter Maintenance Performance "Richtlinien für den Winterdienst auf Strassen, Entwurf 2009". (Snow & Ice Databook 2010, p. 103)

Organization and planning of winter maintenance activities have to be done early and comprehensively because the exact beginning and extent coming winter is nearly unforeseeable. Winter maintenance has to work effectively and efficiently from the very beginning of winter. Only careful planning guarantees a most economical realization of winter maintenance. Therefore the priority plans concerning intensity of treatment and usage of gritting agents has to done. Useful criterions are the following,

- Road category (motorways, federal highways, etc.)
- Traffic volume (AADT)
- Special traffic (roads with public transport or school bus traffic, access roads to rescue service stations, etc.)
- Special accident-prone stops (steep grade, dangerous curves and crossings, stretches with frequent slipperiness in winter such as bridges, roads through forests, extremely shady roads).

A priority list is necessary, especially in urban areas because there winter maintenance can be carried out only successively and not everywhere at the same time. (Snow & Ice Databook, 2010 p. 105)

8.2.1 Snow clearing and de-icing

The strategy persuade in Germany on rural and main urban roads in connection with winter maintenance activities is to achieve again snow-and-ice-free pave-

ments as soon as possible, with the aim of maintaining traffic flow as long as possible and to improve road safety: so-called “bare pavement policy”. (Snow & Ice Databook, 2010 p. 106)

In cases when icy roads can be expected in the near future depending on the weather forecast this policy leads to preventive salt spreading which has been used frequently in the last years. (Snow & Ice Databook 2010, p. 106)

On secondary and lower rank roads in urban areas and in municipalities, in general, where lower driving speeds prevail; “differentiated winter maintenance” is performed. According to the function and the traffic volumes of these roads and streets and depending on weather conditions there is a gradation in the winter maintenance policy: application of de-icing agents on major roads and so-called “zero-gritting”, for example only snow clearing, on the lower streets. (Snow & Ice Databook 2010, p. 106)

Gritting with abrasive matters which was used in former times has become very less common in the last years. A study behalf the Federal Environmental Agency has shown by screening of life-cycle analysis that de-icing materials have less negative ecological effects than abrasives. And other studies concerning traffic safety showed that de-icing materials lead to much lower accident risk on main roads and steep grades in urban areas. (Snow & Ice Databook 2010, p. 106)

According to Snow & Ice Databook , for snow clearing vehicles the following service cycle time-periods for motorways and highways are stipulated (Table 8.4)

Table 8.5 The stipulated cycle time-periods for motorways and highways

Motor and highways which in connection with the motorway network have a significant traffic functions	2 hours (daily 24 hours)
Motorways and interchanges	2 hours (daily 24 hours)
Federal and state highways	3 hours (daily 6 am to 10 pm)

For pure salt spreading activities have distinctly shorter time-periods and standards. The Level of Requirements for Winter Maintenance according to Der Elsner (p. 1121) is given in table 8.6

Table 8.6 Level requirement for Winter Maintenance

Road traffic function	**Time frame**	**Weather or road condition**		
		snowfall, icy roads, hoarfrost	heavy continuous snowfall	severe drifting, avalanches, freezing rain
Motor and highways, which in connection with the motorway network have a significant traffic functions	24 hours (daily)	trafficability on through lanes, interchanges, ramps in junctions and interchanges; passability on parking facilities, shoulders	trafficability on at least through lane per direction of traffic, the most important ramps in junctions and interchanges as well as access roads to service areas, if necessary with snow chains; passability on parking areas without service cannot be any longer guaranteed	trafficability cannot be any longer guaranteed
Important rural roads, roads with strong rush hour traffic, roads with public transport	from 06.00 am to 10.00 pm (daily)	trafficability	trafficability, if necessary with snow chains; on multilane highways at least one through lane per direction of traffic, if required with snow chains	
Further rural roads	appropriate to local traffic demands	trafficability	trafficability, if necessary with snow chains	
Sidewalks, bicycle routes, multipurpose lanes	appropriate to local traffic demands	trafficability, usability for pedestrians	trafficability cannot be any longer guaranteed	
Parking facilities in connection with important and other roads	appropriate to local traffic demands	passability	passability cannot be anylonger guaranteed	

Explanations: "Trafficability" means that obstruction as a result of remaining snow or – according to duration of winter maintenance operation – locally uniform snow covering must be expected, similarly possible local occurrence of slipperiness as a result of hoarfrost or icy roads even after spreading.

"usability of pedestrians" demands that one lane is kept clear of snow and ice to allow two pedestrians to pass each other carefully (approximately 1-1.2 meters).

"passability" on parking facilities and shoulders means that access roads and lanes on parking facilities and shoulders can be used with an adjusted driving behavior appropriate to existing obstructions and that proper parking is possible

"appropriate to local traffic demands" means that winter maintenance is carried out at times demanded by specific traffic. In the individual case this may mean that no winter maintenance is carried out.

Salt consumption has a huge variation for winter maintenance (Figure 8.4). According to Der Elsner (2011, pp. 1095-1096) in the last 10 years averagely 35,8 tons salt per kilometer on motorways and 9,8 tons per kilometer on federal state

highways were spread each winter period. The used types of salt are sodium chloride, calcium chloride and magnesium chloride.

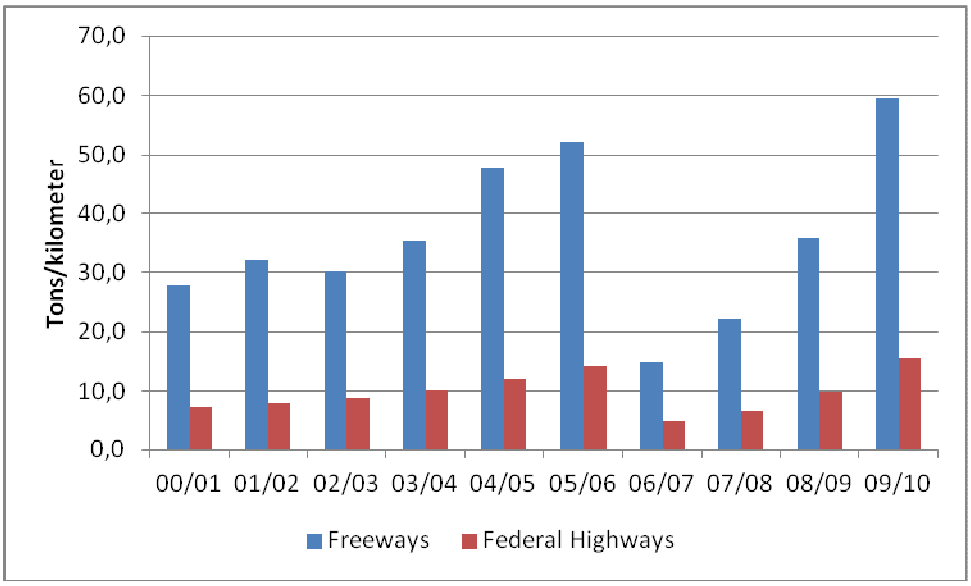


Figure 8.4 Salt consumption in each winter period 2000-2010 (Der Elsner 2011, p. 1095)

The salt consumption shows large differences between the winter periods as can be noticed from the figure. The winter periods 2004/05, 2005/06 and 2009/10 were the heaviest in 10 years bringing a great amount of snow leading to a high salt consumption and high costs.

8.2.2 Costs

There is no budget for winter maintenance, only a yearly budget for road maintenance. Yearly variable expenditures for winter maintenance have to be covered by the budget for road maintenance. This means, that after extreme winters even other road maintenance tasks have to be postponed to a certain extent; after extreme strong winter even additional funds from the construction budget are necessary. (Snow & Ice Databook 2010, p. 107)

Averagely, the cost of the winter maintenance during 2000-2010 was on motorways 6 930 €/kilometer and on federal state roads 1 818 €/kilometer. (Der Elsner 2011, pp. 1095-1096). Costs in each winter can be seen from figure 8.5.

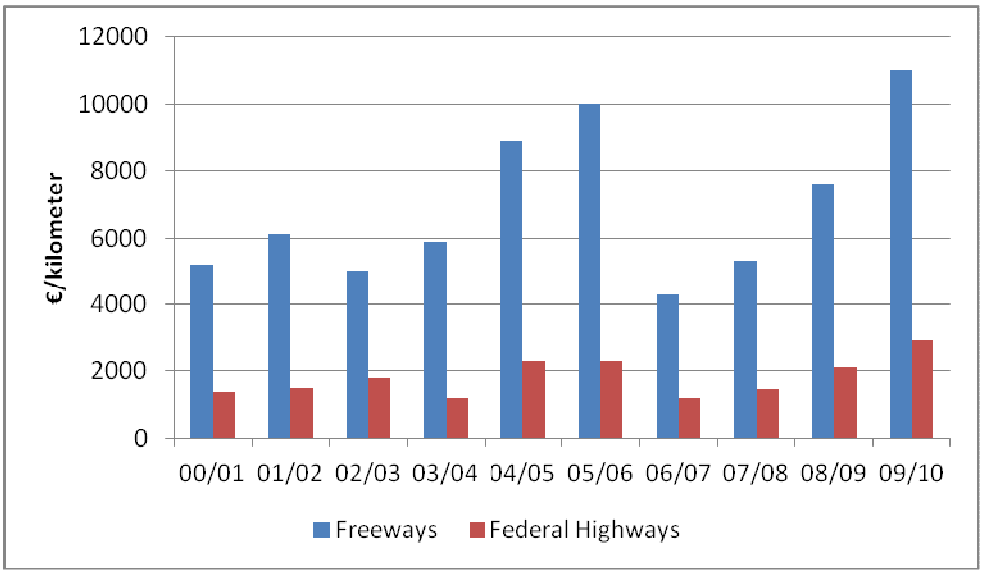


Figure 8.5 Average costs of winter road maintenance in Germany (Der Elsner 2011, pp. 1095-1096)

The higher costs on motorways can be explained by them being equivalent to four lane roads, whereas federal state highways have only two lanes. The distribution of the costs is quite similar compared to salt consumption in figure 8.2. Strong winters make the rise of the costs inevitable.

8.3 Summary

The main measures in winter maintenance are pretty similar in Finland and Germany. The leveling of the road surface is not used in Germany because of lack of packed snow on the roads but de-icing and snow clearing are main operations in both countries. Also, there are no big differences in the cycle time-periods for snow clearing. It is notable, that the stipulated cycle-time on federal and state highways is similar as on the roads in winter maintenance class III in Finland.

Salt is widely used in both countries. In Germany it is used as the main de-icing measure on all roads but in Finland only in the two highest maintenance classes and partly in the two lower ones. Salt consumption in Germany is much higher which can be explained by the abrasive matters which are not used in Germany but are common in Finland on the most parts of the road network.

The cost of winter maintenance on motorways is much higher than the total cost of winter maintenance per kilometer on class Is roads in Finland. On the other

hand the costs on the federal state roads is smaller than the costs in maintenance class Is and I in Finland.

Traffic volume causes differences to winter maintenance. On the roads of heavy traffic already small changes of weather can cause big problems. On the other hand, small traffic volume and big amount of snow do not make clean road surface possible during winter in Finland. Due to this the quality requirements have to be different and what works in one country would not work in the other one.

What is also remarkable is that in distinction to Finland, in some cases trafficability and passability are not guaranteed in Germany.

9 CONCLUSIONS

The purpose of the thesis was to take a look at the road maintenance in Finland and Germany and find out differences and different things that have an effect on it. In my opinion the goal was gained by the comparison which gives a clear picture of the road maintenance in general level. The orderer of this thesis, YIT Construction Ltd, was satisfied with the results of this study hence the aim was achieved so far as well.

It is important to improve road maintenance measures but the results show, that they cannot be copied easily from one country to the other due to the different circumstances which are mentioned in the study.

The greatest challenge for road maintenance in Finland is strong winter. Winter sets a great challenge in Germany too, but even more challenging is an enormous traffic volume which requires flawless and rapid maintenance without risking traffic safety. These are the requirements in Finland too, but due to smaller traffic volumes they are easier to gain. There could also be a possibility to improve winter maintenance in Germany with the Finnish methods and know-how but as mentioned before, large traffic volume could be a problem because in Finland road maintenance methods do not have to face the challenges set by it.

One of the biggest differences is in the organization level. Unlike in Germany, the whole road maintenance is privatized in Finland. This has led to smaller costs of road maintenance while in Germany the costs have been rising every year. The model of Finland could be difficult to execute in Germany, but in Finland it has lowered the costs without that the quality has endured.

Making this thesis offered me many new and different kinds of perspectives concerning not only road maintenance but also the circumstances that have a great effect on it.

FIGURES

TABLES

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APPENDIX 1

	Finland	Germany
Road Network	78 161 km	230 970 km
Motorways	765 km	12 813 km
Total mileage	35,87 billion automobile kilometres	402,8 billion automobile kilometres
Climate conditions	Hard winter	Medium winter
Winter speed limits	Yes	No
Use of studded tires	Allowed	Prohibited
Tendering of the road maintenance	Totally tendered	Partly tendered
The cost of the road maintenance	1428,62 e/km (maintenance contract	7285 e/km
The cost of the winter maintenance	2900 e/km (two lane roads)	1818 e/km (federal highways)
The cost of the winter maintenance on motorways	8900 e/km	6930 e/km
Average salt consumption	80 000 tons	850 000 tons (motorways and federal highways)
Use of sand as a gritting agent	Yes	No
Trafficability guaranteed	Always	Not always