

# OPTIMAL USE OF VEHICLES IN WINTER MAINTENANCE OF AUTOBAHNS IN GERMANY

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## 1. Abstract

The range of the winter maintenance activities and here in particular the cover of the requirement for clearing operations in strong snowfall is regarded as the most important criterion for the calculation of the vehicle configuration of autobahn maintenance depots. Due to organisational modifications in the technical road service and technical advancements with vehicles and devices in the last years substantial boundary conditions for the calculation of the configuration changed. Therefore in a research project of the Federal Ministry for traffic in Germany the calculation principles for the vehicle configuration of autobahn maintenance depots were checked. In order to be able to ensure a high quality of the technical road service as economically as possible, the following boundary conditions are relevant:

1. A minimum equipment for the accomplishment of the winter maintenance requirement for the case of calculation "clearing the entire road network " is necessary.
2. The vehicles of the autobahn maintenance depot must be as highly as possible working at full capacity during the whole year.

The analysis of the clearing and strewing performances of different combinations of vehicles with units stands in the centre of the research as well as the question how different types of the organisation of winter maintenance affect the clearing and strewing performance and thus on the vehicle and device requirement. The results of the winter maintenance operational analysis and the analysis of the vehicle operation hours in representatively selected autobahn maintenance depots were basis for a view of economy, in which the costs of different vehicle configurations were compared together by taking the capacity of all-season vehicle into account.

As result of the research project a method to optimise the use of vehicles on autobahns was developed. With this method recommendations regarding the configuration of autobahn maintenance depots with vehicles could be demonstrated for Germany. This led to substantial savings. Further more, consequences for practice could be derived, which offer the responsible dispatcher an assistance within unfavorable conditions. This effects especially the use of heavy or middle truck versus Unimog, the clearance of roadways with several vehicles in relay versus single vehicles, the schedule for a district with a proportion of three or four lane roads and the assignment of work to private contractors for the accomplishment of peak loads or for the care of special sections such as steep roadway sections or large valleybridges.

## 2. Inducement

In Germany, special motorway surveillance centres are responsible for the operational road maintenance of the motorways. Their equipment with vehicles and tools for winter maintenance represents a significant cost factor.

The amount of winter maintenance turnouts and in this context especially the demand of clearance turnouts at heavy snowfall is often described as the most important criterion for the allocation of the vehicle equipment of motorway surveillance centres. However, in the past fundamental conditions

have changed: This includes technical developments of vehicles and tools of winter maintenance (more powerful engines and hydraulic systems) and organizational changes because of a reduction of surveillance centres and extension of the treatment length up to 70 kilometers and more.

These changes were taken for an opportunity to review the allocation of the vehicle equipment of motorway surveillance centres. To guarantee a high standard of operational road maintenance as economically as possible, two conditions are decisive:

- Optimal capacity utilization of vehicles all year round on the basis of a analysis of the annual vehicle operation hours
- Minimum equipment to face the demand for winter maintenance on the calculation case “snow clearing in the whole road network”

The following presentation is based on two research projects, which were realized on behalf of the Federal Minister of Transport in the years 1995 and 1997. The operational hours of a whole year were investigated in [1] on the basis of an extensive evaluation. Recommendations for vehicle equipment of standard surveillance centres were deduced out of this investigation. Turnouts on motorways were analyzed extensively to secure the results of examination in view of demand of tools and to be able to evaluate the influence of different marginal conditions on calculation criterions. In the centre of attention were performances of snow clearance of different vehicle-tool combinations. Another question was, how different systems of turnouts effect the performance and the demand of vehicles and devices.

### **3. Method of investigation**

At the beginning of the investigation 10 motorway surveillance centres with different profiles were selected, to analyse winter maintenance extensively. In addition all motorway surveillance centres in Germany were written concerning the execution of winter maintenance in order to contribute practical experiences. The response of the questionnaires were 90%, so that the conclusions were considered as very reliable.

The minimum vehicle- and tool- equipment for winter maintenance was dimensioned on the basis of the turnouts for the case “snow clearing in the whole road network”. Basis for dimension was an “average motorway surveillance centre” with a straight two-lane network of 70 km length and 35 km one- or two-lane ramps and supplementary-lanes. Thereby the aimed level of service for winter maintenance in Germany as well as appropriate specifications were considered. The winter maintenance planning is based on the operating speed as performance parameter, which were established by the evaluation of tachograph discs of selected motorway surveillance centres.

Beginning from a minimum equipment for turnouts, different equipment variation concerning the capacity utilization of the vehicles throughout the whole year were compared. Within economic evaluation an analysis comparing the costs was carried out for these equipment variations.

Examples of typical vehicles, used at German motorway surveillance centres as system carriers for tools of winter maintenance, and which were focused in the investigations, are shown in Picture 1; technical data referring on winter maintenance are shown in Picture 2.



Multi-purpose equipment carrier  
(UNIMOG, 110 kW)



Heavy duty equipment carrier  
(UNIMOG, 176 kW)



Midsize equipment carrier (MAN, 147 kW)



Large equipment carrier (MAN, 205 kW)

**Picture 1: Typical vehicles used by German motorway surveillance centres as equipment carriers for winter maintenance**

	total weight	total axle load, front (Wintermaintenence)	total axle load, rear (Wintermaintenence)	capacity of gritter	clearance width frontplough / sideplough
Large truck (dubl. rearaxles)	26 - 30 t	8 - 10 t	19 - 26 t	6 - 9 m <sup>3</sup>	to 4,4 m / 2,6 m
Large truck (two axles)	17 - 20 t	8 - 10 t	10 - 13 t	4 - 6 m <sup>3</sup>	to 4,4 m / 2,6 m
Heavy duty equip. carrier (U 2400 TG)	21 t	7,3 t	13,5 t	4 - 6 m <sup>3</sup>	to 4,4 m / 2,6 m
Multi purpose equip. carrier large (U 1600 - U 2150)	11 - 13 t	7 t	7 t	2 - 2,5 m <sup>3</sup>	to 3,4 m / -
Multi purpose equip. carrier mid (U 1000 - U 1450)	8,5 - 11 t	4,9 - 6,6 t	5,5 - 6,6 t	1,5 - 2 m <sup>3</sup>	to 3,4 m / -

**Picture 2: Technical data of vehicles, used as equipment carriers in Germany**

## 4. Results

### 4.1 Demand of vehicles for winter maintenance

The demand of vehicles for winter maintenance turnouts arises first of all from the characteristic of treatment length and less from peculiarities of the regional climatic area, a motorway surveillance centre belongs to. Reason therefore is, that fundamentally in all areas of Germany heavy, long lasting snowfall must be taken into account. Differences exist more in the frequency of the happening of a special weather and with that in the corresponding number of calls for winter maintenance (clearance, gritting).

With a starting slipperiness, the factor time is over all decisive, to guarantee a good level of service and safety to keep up a smooth traffic flow as well as the capacity of the road network. Possibilities of optimizing the cycle time were checked for all phases of a turnout, preparation of the first turnout, the turnout itself and the preparation of the following turnout (for example: reloading),. Saved time can be used to improve the level of security and service as well as in view of economic aspects.

Especially in case of the improvement of economic aspects it is necessary to pay attention to the proportionality and to check, if a single action really improves the overall result noticeably. E. g. the assembly of the grit spreader as fast as possible is only required, if the concerning vehicle isn't used with assembled grit spreader (e.g. for traffic safety) throughout the whole winter anyway.

An average surveillance centre with 2 x 70 km two lane motorways arises a minimum demand of 4 big trucks for clearing and gritting in a desired tour time of less than 2 hours and 2 further vehicles (e.g. multi-purpose- or heavy-duty-equipment carriers) for the service of interchanges, ramps and supplementary-lanes. The required time exposure depends on, if the turnouts are carried out with a squadron of vehicles or only with single vehicles. The calculation is based on the following operating speeds:

- Clearance/ clearance and gritting at 35 km/h
- Gritting at 45 km/h
- Drive at 60 km/h (empty or with full load)

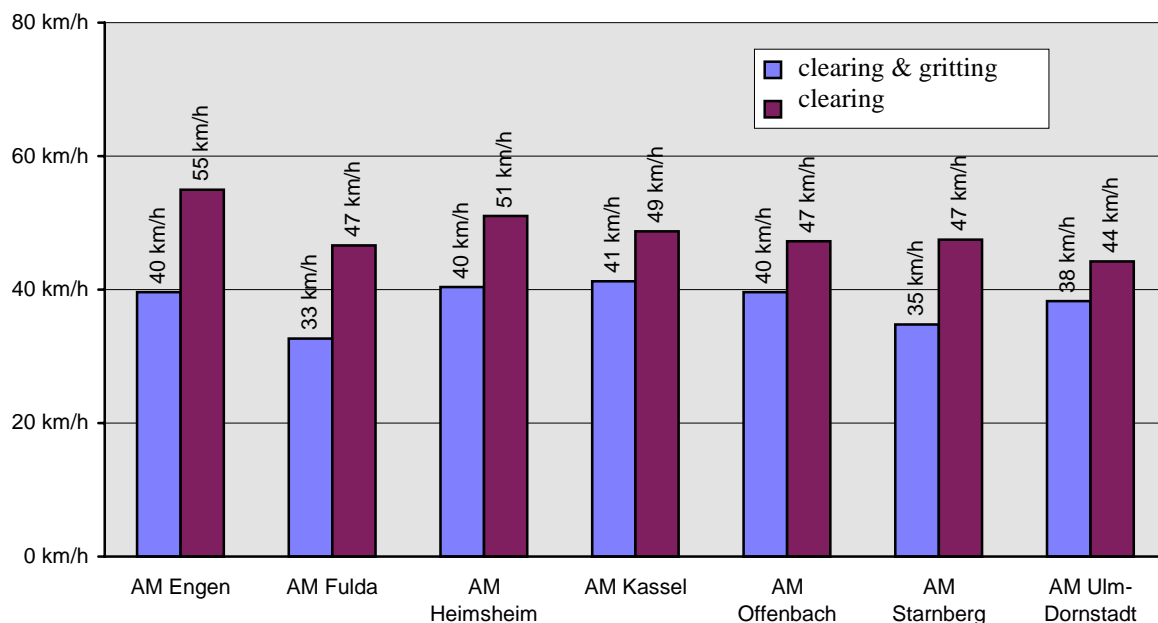
These values were confirmed by an extensive analysis of tachograph discs from 10 motorway surveillance centres (shown in picture 3).

A 5 m<sup>3</sup> grit spreader up to a spread rate of 35 g/m<sup>2</sup> for every of the 4 trucks is sufficient for a treated length of 35 km and nonstop two-lane carriageways. 6 x 5m<sup>3</sup> grit spreaders are required to spread up to 40 g/m<sup>2</sup>.

The demand of vehicles is even higher, when good conditions (nonstop two-lane carriageways, average volume of traffic, central location of the surveillance centre, average interchange density) are not given.

With an increasing share of three-lane motorways increases first of all the requirements of gritting material per kilometer. In view of snow clearance initially no additional demand occurs, because 2 clearance vehicles in squadron can clear 2 as well as 3 lanes (depending on the width of the tool assembled) completely in one turnout. The higher amount of gritting material can still be covered, at a maximum spread rate, by the use of 6 m<sup>3</sup> grit spreaders, if the part of three-lane carriageways is maximum 3 km at a total length of 35 km. With a higher part or complete three-lane carriageways the following solutions should be examined, if it is not possible going without gritting with a high spread rate:

- Extension of the operation time through reloading. This represents the cheapest solution, because no additional or bigger vehicle is required.
- Use of bigger grit spreaders (over 6 m<sup>3</sup>) on three-axles without additional staff
- Use of additional (if necessary: rented) vehicles to shorten the clearance- / gritting turnouts



**Picture 3: Average operating speeds for clearance- and gritting turnouts in selected motorway surveillance centres**

On sections with a high traffic volume or high longitudinal slope (higher than 4%) exists an extended risk of traffic jam at wintry road conditions and for that reason the risk, that the cycle time of the vehicles is extended. In that case, but also to reduce the risk of a traffic jam by shortening the cycle times, additional demand of vehicles arises. An estimation of the additional demand of vehicles is only possible on the basis of experiences at the specific location, because the risk of a traffic jam depends on many factors. The use of a higher number of smaller trucks with less clearance-width (and consequential with less clearance) especially in view of obstructions of the trucks in a traffic jam is not recommended, because the use of vehicles with bigger clearance-width usually is more economic. For cases of emergencies for some trucks small snow ploughs can be hold in reserve or the existing multi-purpose-equipment carriers can be used.

Disadvantages because of non-central locations of the surveillance centres can be compensated by setting-up winter maintenance points, to avoid, empty trips to reload the truck for another turnout.

A higher frequency of interchanges can where required be handled by lengthening the clearance turnouts for the trucks or equipment carriers.

#### 4.2 Capacity utilization of vehicles in all year round use

In the course of the investigations there was distinguished between the categories “motorway surveillance centre in urban areas” and in “motorway surveillance centre in rural areas”. Significant for these categories are the differences in the volume of the annual grass cutting and the traffic volume, which influences the number of calls for accidents safe guarding.

The operational street maintenance in Germany is more and more be subject to the pressure towards task-critics and towards the adaptation to changing margin conditions. To take these changes into account calculation basis of the number of operating-hours with important objectives (e.g. traffic safety and transport trips) were correspondingly adapted.

In order to relieve the road administration, to go without traffic safety it is planned to neglect safe guarding for other companies in the future and to shorten the calculation basis for traffic safety by 30%. The 30% share was an average value given in the survey of the motorway surveillance centres.

Moreover it can be estimated, that it's possible to shorten the expenditure on transport capacities by optimizing transport activity.

A part of the transport capacities can be taken over from other vehicles (for example transportation of small load or staff by a road guard vehicle or a van).

Good experiences were achieved with the use of rollof and drop dumpers. This aspect results into a 25% -reduction of transport time versus the basis found out in the investigation.

The evaluation of the survey of the motorway surveillance centres did not show recognizable differences concerning the size of the winter maintenance, which would justify a further deviation into regional surveillance centres. The very complex combination of the different factors, which influence sort and size of the winter maintenance turnouts, does not allow a useful categorization of the motorway surveillance centres.

To the categories “average motorway surveillance centre in rural area” and “average motorway surveillance centre in urban area (plain area)” a task-scope as shown in picture 4 was determined.

motorway surveillance centre	urban area (plain geography)	rural area
road network length	70 km	
winter maintenance:		
average gritting time per winter	570 h (240 h)	570 h (240 h)
average clearing and gritting time per winter	940 h (240 h)	940 h (240 h)
average control time per winter	270 h (40 h)	270 h (40 h)
other activities:		
mow activities	450 h	330 h
washing lodeposts	130 h	130 h
other equipment carrier activities:	1.280 h	1.280 h
transportation	3.400 h	3.400 h
garantee of traffic safety	2.700 h	1.800 h
garantee of traffic safety for clients	-	-
other	640 h	640 h

Value in brace: contingent of regular working hours

**Picture 4: Task- scope (hours/ year) in an “average motorway surveillance centre”**

The utilization of the vehicles results from the rate on duty between the maximum number of hours, which are possible with a particular equipment (90% of the available working hours) and the required on duty hours (in account of equipment service and repairs). Only operating hours are taken into consideration, which occur throughout the regular working time. Picture 5 shows the calculation of the utilization of vehicles for one equipment variation.

action	truck (large)					multi purpose equipment carrier (midsize)				
	summer		winter		year	summer		winter		year
	RAZ	RAZ	SZ	Σ	RAZ	RAZ	RAZ	SZ	Σ	RAZ
clearing	0 h	160 h	220 h	380 h	160 h	0 h	40 h	55 h	95 h	40 h
gritting	0 h	160 h	560 h	720 h	160 h	0 h	40 h	70 h	110 h	40 h
control tours	0 h	40 h	230 h	270 h	40 h	0 h	0 h	0 h	0 h	0 h
washing lodeposts	0 h	0 h	0 h	0 h	0 h	25 h	105 h	0 h	105 h	130 h
Mow activities	0 h	0 h	0 h	0 h	0 h	0 h	0 h	0 h	0 h	0 h
other equipement carrier activities	0 h	0 h	0 h	0 h	0 h	200 h	475 h	0 h	475 h	675 h
transportation	1.700 h	1.600 h	0 h	1.600 h	3.300 h	0 h	0 h	0 h	0 h	0 h
other activities	210 h	210 h	0 h	210 h	420 h	55 h	55 h	0 h	55 h	110 h
garantee of traffic safety	900 h	900 h	0 h	900 h	1.800 h	0 h	0 h	0 h	0 h	0 h
Working hours (total)	2.810 h	3.070 h	1.010 h	4.080 h	5.880 h	280 h	715 h	125 h	840 h	995 h
share maintenance / repairs	10%			10%		15%			15%	
maintenance / repairs	281 h	408 h	←	408 h	689 h	42 h	126 h	←	126 h	168 h
necessary employment hours	3.091 h	3.478 h			<b>6.569 h</b>	322 h	841 h			<b>1.163 h</b>
maximum possible employment hours	3.912 h	3.881 h			7.792 h	978 h	970 h			1.948 h
load (referred to 100 %)	79%	90%			84%	33%	87%			60%
maximum possible employment hours	3.520 h	3.493 h			7.013 h	880 h	873 h			1.753 h
<b>load (referred to 90%)</b>	<b>88%</b>	<b>100%</b>			<b>94%</b>	<b>37%</b>	<b>96%</b>			<b>66%</b>

action	heavy duty equipment carrier					overall vehicles				
	summer		winter		year	summer		winter		year
	RAZ	RAZ	SZ	RAZ	RAZ	SZ	RAZ	RAZ	GES	RAZ
clearing	0 h	40 h	55 h	95 h	40 h	0 h	240 h	330 h	570 h	240 h
gritting	0 h	40 h	70 h	110 h	40 h	0 h	240 h	700 h	940 h	240 h
control tours	0 h	0 h	0 h	0 h	0 h	0 h	40 h	230 h	270 h	40 h
washing lodeposts	0 h	0 h	0 h	0 h	0 h	25 h	105 h	0 h	105 h	130 h
Mow activities	330 h	0 h	0 h	0 h	330 h	330 h	0 h	0 h	0 h	330 h
other equipement carrier activities	125 h	480 h	0 h	480 h	605 h	325 h	955 h	0 h	955 h	1.280 h
transportation	0 h	100 h	0 h	100 h	100 h	1.700 h	1.700 h	0 h	1.700 h	3.400 h
other activities	55 h	55 h	0 h	55 h	110 h	320 h	320 h	0 h	320 h	640 h
garantee of traffic safety	0 h	0 h	0 h	0 h	0 h	900 h	900 h	0 h	900 h	1.800 h
Working hours (total)	510 h	715 h	125 h	840 h	1.225 h	3.600 h	4.500 h	1.260 h	5.760 h	8.100 h
share maintenance / repairs	15%			15%						
maintenance / repairs	77 h	126 h	←	126 h	203 h	400 h	660 h	←	660 h	1.060 h
necessary employment hours	587 h	841 h			<b>1.428 h</b>	4.000 h	5.160 h			<b>9.160 h</b>
maximum possible employment hours	978 h	970 h			1.948 h	5.867 h	5.821 h			11.689 h
load (referred to 100 %)	60%	87%			73%	68%	89%			78%
maximum possible employment hours	880 h	873 h			1.753 h	5.281 h	5.239 h			10.520 h
<b>load (referred to 90%)</b>	<b>67%</b>	<b>96%</b>			<b>81%</b>	<b>76%</b>	<b>98%</b>			<b>87%</b>

RAZ = hours while regular working hours

SZ = other hours beyond regular working hours

**Picture 5: Example for utilization of vehicles; here: 4 trucks, 1 heavy-duty equipment carrier and 1 multi-purpose equipment carrier at a motorway surveillance centre in a rural area.**

The calculated minimum equipment of winter maintenance (4 trucks and 2 multi-purpose equipment carriers) is, according to the results of the utilization analysis, as well sufficient for all other tasks of a motorway surveillance centre in rural areas. A heavy-duty equipment carrier as universal-vehicle is recommended instead of a multi-purpose equipment carrier to increase the flexibility, for winter maintenance in case of one of the vehicle breakdown.

For a motorway surveillance centre in an urban area (plain area) 5 trucks and 2 multi-purpose equipment carriers are required, because of the higher number of accident safety guarding jobs and more frequently grass cutting works in plain areas.

An average utilization of the trucks of around 90% and of the multi-purpose equipment carriers of around 75% results with the recommended equipment variants, referring to the type of motorway surveillance centre. The utilization in winter is generally higher than in summer.

## 5. Consequences in practice

Under good conditions (nonstop two-lane carriageways, central located surveillance centre) 4 trucks and 2 multi-purpose equipment carriers are sufficient for winter maintenance in a motorway surveillance centre with a treatment length of 70 km.

Based on the spread rate normally required, for a motorway surveillance centre with nonstop two-lane carriageways it's recommended, to equip the trucks with a 5m<sup>3</sup> grit spreader and the multi-purpose equipment carrier with a 2m<sup>3</sup> grit spreader. With this equipment it is possible to obtain a spread rate of 35 g/m<sup>2</sup> at clearance and gritting slopes of a length of 70 km (two-lane carriageway) with a squadron of 2 vehicles without reloading. At the same conditions 6 m<sup>3</sup> grit spreaders allow spread rate up to 40 g/m<sup>2</sup>. 6 m<sup>3</sup> grit spreaders can be assembled with a subframe-construction on two axle trucks or a heavy-duty equipment carrier.

Additional requirement (additional vehicle, higher capacity of grit spreader, greater clearance-width) results, when part of the treated network is three-lane, especially because of the additional required grit material. Depending on the extension of the three-lane sections the following measures are recommended:

- Extension of the tour time through reloading
- Use of bigger grit spreaders on three-axle vehicles
- Additional use of vehicles (if necessary: rented) to shorten the clearance- /gritting turnouts

Demand for additional winter maintenance capacities (additional vehicle, higher capacity of grit spreader, greater clearance-width) may occur when essential conditions change (greater traffic volume, treatment length with high longitudinal slopes, non-central location of the surveillance centre, high frequency of interchanges).

Clearance with a squadron of vehicles is more economic than clearance with single vehicles, because one cycle is required only for clearance of the carriageway and at for the cselection of the grit spread rate a non-cleared lane must be taken into account.

For staggered clearance of a nonstop two-lane carriageway the use of 2 trucks with over-width front-snowplough is recommended (effective clearance-width: 8,00 m). At partly or nonstop three-lane carriageways 2 trucks with over-width front-snowplough and side-snowplough (effective clearance-width: 11,80 m) are required. If staggered clearance turnouts are not possible, single carriageways can be cleared with an over-width front-snowplough without side-snowplough (effective clearance-width: 4,20 m) or at reduced clearance-width with front-snowplough without additional plough (effective clearance-width: 3,20 m).

Cost for the operation of more vehicles with less clearance-width is higher than the use of combinations of vehicles with a snow plough width as possible. For the treatment of sections with an especially high risk of traffic jam a part of the vehicles can be used with front-plougher with less clearance-width. A multi-purpose equipment carrier can also be used. In addition the equipement of these clearance vehicles with blue lamp and siren has to be checked.

In view of capacity utilization in all year round operation of winter maintenance corresponding to the actual level of service for winter maintenance in Germany: "Guarantee of passage for the nonstop carriageway in an intendet cycle time" of at least 2 hours" with vehicles owned by the road administration itself is useful and economic. If vehicles are required in addition, rented vehicles should be brought into operation, because the purchase of additional vehicles in view of the utilization all year round isn't economic. To rent vehicles could be useful in the following cases:

- The completion of single-operated, vehicles, owned by the road administration itself, to vehicle units
- Clearance and gritting of ramps and supplement lanes
- The performance of further turnouts to the relief of the surveillance center staff
- Additional treatment of problematic sections (e.g. bridges or uphill stretches) with rented vehicles, when a contractor is located close this section which would guarantee a quick operating time



Only heavy-duty equipment carriers or big trucks (as equipment carriers) can be seen as a “Universal vehicle”, but not mid-size truck as equipment carrier. This applies under consideration of the winter maintenance and because of the permitted axle load for grit spreaders from 4 m<sup>3</sup>.

Under extended renunciation on traffic safety for third persons (strived in Germany) and by optimizing transport turnouts the following vehicle equipment is sufficient for motorway surveillance centres with a treatment length of 70 km:

- In case of an “average motorway surveillance centre in a rural area” under favorable conditions: 2 mid-size multi-purpose equipment carriers and 4 big trucks. However, to increase flexibility and to keep up the carrying out of the winter maintenance in full extent the use of a heavy-duty equipment carrier instead of a multi-purpose equipment carrier is recommended.
- For an “average motorway surveillance centre in an urban area (plain area)” there are 2 mid-size multi-purpose equipment carriers and 5 big trucks required, because of the extended expenditure in grass cutting in summer and the higher number of accident safety guarding jobs (because of the higher traffic volume in metropolitan areas).

From that, an average capacity of utilization of the trucks of around 90% and of the multi-purpose equipment carriers of around 75%, referring to the type of motorway surveillance centre, results for the all year round operation. In general, utilization in the winter is higher than in summer.

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