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POSSIBILITIES AND LIMITATIONS IN METROPOLITAN STREET MAINTENANCE IN WINTER

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Urban street maintenance in winter is especially complicated by concentrated traffic load, spatial narrowness, intersections, pedestrian walkways and overpasses. It consists in clearing and surface treatment [spreading salt, sand, etc.] at busy and dangerous locations. Construction firms are used for clearing operations. In Munich winter street maintenance covers 26 million m^2 of roadway, 800 km of sidewalk, 28,000 pedestrian crossings, and approximately 3500 individual sites. Expenditures in winter 1969/1970 for November → next page

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to April are shown in diagram form (snow removal, sand and salt truck use, sand and salt consumption, labor, output value). Costs totaled 11 million DM for this extremely severe winter. Thus economically acceptable upper critical value was reached.

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NOTICE

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1. Preliminary Remarks

Street maintenance in winter is more in the public eye in cities than anywhere else. As traffic increases, the demands and at the same time the problems for operating methods as well grow. As in other areas of the environment, in winter street maintenance, growing prosperity may be a decisive impetus for higher and higher demands for comprehensive perfection. Symptoms of this include diminishing willingness to tolerate weather-related aggravations in traffic from time to time or to become active oneself within the framework of citizen assistance. The work of urban road construction administrations is accordingly subjected to sharp public criticism in the winter months. The demands thus placed on winter street maintenance may in many cases be justified. Often enough, however, they exceed any yet feasible or economically justifiable measure, and even the highest judicial findings in this area are occasionally encumbered by rather impractical or even utopian ideas of capabilities and limitations of winter street maintenance. Certain problems of metropolitan winter maintenance based on examples of operating practice in Munich will be pointed out with the following comments.

2. Special Features of Urban Street Maintenance in Winter

Urban street maintenance in winter is complicated by various influences and circumstances, in contrast to winter road maintenance on rural roads and highways. Among these are:

-- hindrances by the concentrated traffic load on urban streets, primarily by parked vehicles which may make the clearing of curb lanes and thus gutters essential during thaws impossible,

-- the extensive closeness in the urban area without sufficient room for depositing snow, so that snow more or less must be eliminated, i.e., hauled away or melted,

-- the combined demands of individual motorized traffic, pedestrian traffic and mass transit systems being considered at the same time,

-- operating difficulties caused by the dense network of intersections and junctions, also by approaches to lots, pedestrian bridges, stopping places, etc.

In addition to these features which complicate operation, urban street maintenance in winter is charged with further duties. In contrast to public roads outside closed locales, there exists within closed locales a legal obligation to clear and treat all areas which may be important for traffic and dangerous. Included here are hill sections, overpasses and underpasses, curves, intersections, railway crossings and above all the numerous pedestrian crossings and mass transit stops.

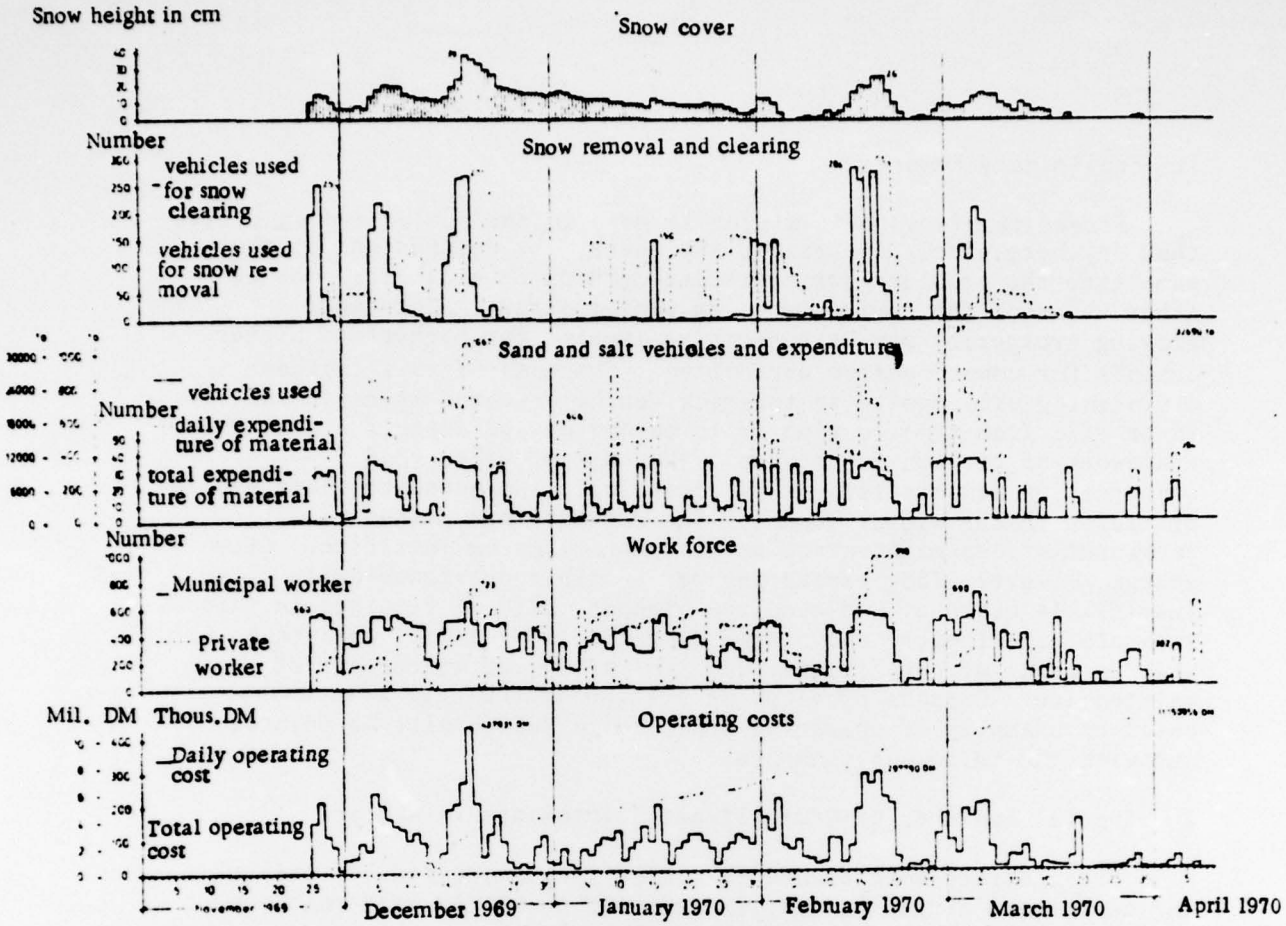

Figure 1. Winter Road Maintenance Graphs in Munich in 1969/70.

A decision of extraordinary influence on operations organization and capacity was made some time ago by the Federal Court in its finding that the timely, regular treatment of pedestrian crossings by no means suffices; rather under extraordinary circumstances busy essential pedestrian crossings over roadways must be sprinkled in each case within three hours after the advent of a dangerous situation. Aside from the fact that a practical, universally understandable and explainable definition of the concepts "essential" or "busy" can hardly be obtained and therefore must be left to individual intuition in each particular case, the establishment of the three-hour time limit for the safety of pedestrian crossings outside the regular cycle seems exaggerated as well and at least in larger cities generally neither feasible nor economically justifiable in practice.

3. Personnel Problems, Use of Private Concerns

Most of the special features of winter street maintenance in the urban areas result in the fact that here operations lend themselves less to mechanization and require larger capacities, especially more personnel. However, it is in cities that the need for personnel, in view of full employment, is much more pressing than in the country

and has already become in many places a decisive limitation for winter street maintenance plans. At least in climatically unfavorable areas the capacities existing in the city street construction and street maintenance bureaus are not even normally adequate for regular winter road maintenance and hardly for the peak demand under heavy winter conditions. Nor would it without a doubt be right to measure the personnel strength of the road administrations by the peak demand in winter. The use of construction firms and shipping concerns engaged in the construction industry for winter road maintenance, i.e., outside the building season, seems reasonable from a personnel and cost point of view. For example, in Munich at present approximately 60% of all roadways are being cleared of snow by private firms on the basis of long-term performance contracts with strictly defined tasks and duties, and salting and sanding operations are being conducted by private firms to an almost equally proportional degree. In addition, a large number of administrative work agreements have been concluded to meet the peak demand. Although the performance agreements can be financially quite attractive with built-in stand-by fees to be paid regardless of the amount of work performed, great difficulties are presently arising in procuring further contractors for deadline-pressure winter road maintenance. The difficulties thus result less from a general lack of interest in undertaking the generally well-remunerated work than from the apprehension of losing labor by allocation to winter street maintenance.

4. Economic Considerations

Obviously the available capacity for winter street maintenance is limited not only by the time and ecomomic difficulties mentioned above, but also by financial considerations. It is unjustifiable to allocate so many vehicles, equipment and personnel that in any weather situation the entire road network can be cleared and treated in a short time. Rather it must be considered with allowance for special local and climatic conditions to what extent and with what frequency a limited traffic safety situation on the streets still seems acceptable. One winter's operation should be carefully analyzed to obtain this data. A useful index for weighing the economic feasibility of reserved vehicle or equipment units can serve as a utilization factor for them. Thus we should proceed either from the average of several winters or the utilization factor in one winter with severe weather conditions (for southern Bavaria, for example, from the data of the winter of 1969/1970). The utilization factor can be defined variously:

The "theoretical utilization factor" $v_{Th.i}$ of type i units is calculated for a concentrated uninterrupted succession of n days, for example for the total duration of winter road service, according to

$$v_{Th.i} = \frac{\sum k_t \cdot 100}{n \cdot k_{t,max}} \quad [\%]$$

where $k_{i,max}$ -- maximum available number of type i equipment units,

k_i -- on day 0.....n number of i type equipment units used (differentiation according to the daily hours of usage is generally not necessary).

The "effective utilization factor" r_{eff} of type i units is calculated for n_i days on which at least one piece of equipment was used, i.e., only for the effective days of winter street maintenance use, according to

$$r_{eff} = \frac{\sum_{n_i} k_i \cdot 100}{n_i \cdot k_{i,max}} [\%]$$

Since during the entire winter street maintenance period equipment for other work is mostly not available or only so to a limited extent, the "theoretical utilization factor" is preferred to the "effective" factor for a comparison of economic feasibility.

5. Analysis of an Operating Cycle

What statements are possible based on an operations analysis will be subsequently shown by way of an example on the basis of the operating cycle during the 1969/1970 winter.

Within the framework of winter street maintenance, approximately 2000 km or 16 million m^2 of roadway surface, approximately 800 km of sidewalks in the inner city street cleaning connecting area and some 3500 km of primarily unconnected individual surfaces on sidewalks in front of city sites must be maintained. Added to this are approximately 28,000 pedestrian crossings, mass transit stops and other special hazardous locations. Table 1 contains indicative weather data for the 1969/1970 winter under examination with comparison data. Accordingly this unusually long but not very cold winter was distinguished primarily by a previously unmatched total snowfall of 161 cm and 111 days with an unbroken snow cover. The weather situation this winter seems especially suited for a critical operations analysis.

Table 2 gives a rough performance summary for the 1969/70 winter with comparison data for the previous 1968/69 winter; Figure 1 provides a simplified graphic representation of the winter street maintenance cycle from 11/1/69 to 4/9/70. Some interesting conclusions can be drawn with regard to clearing, treatment and removal operation from the charts.

Snow Clearing

Equipment reserved for clearing snow was almost completely used only on very few days because of the extremely snowy winter, and then practically only on days with at least 10 cm new snow. According to weather bureau statistics (Table 1), there are only two days per winter

in Munich with 10 cm or more new snow on the long-term average. The entire clearing capacity is correspondingly needed hardly more than two days a winter on the average. In snowfalls up to 10 cm the I, II and III priority road system can be cleared at the same time and within approximately four hours. Only on days with a greater snowfall must a longer clearing time or clearing operations on a priority basis be tolerated. Wherever possible, mechanical clearing is supported by combined salt spreading. Further increases in the clearing equipment held in reserve hardly seem justified, as can also be seen from the theoretical utilization factors given in Table 3 for clearing equipment of at most 21.8% in November/December 1969 or on the average 12.9% in the entire winter. Only on five days, that is 3.8% of all winter days, was it necessary to use more than 80% of available clearing equipment, while on 103 days, that is 77.5% of all days of the winter period under examination, only between 0 and 10% of clearing equipment was used (Table 4).

Analysis yielded further that expense for mechanical clearing of each cm of daily new snow increased greatly as the amount of new snow drops.

TABLE 1. WEATHER CONDITIONS IN MUNICH IN WINTER 1969/70 (INCLUDING COMPARISON VALUES)

	Nov.	Dec.	Jan.	Feb.	March	Winter
1. Anzahl der Tage mit geschlossener Schneedecke (≥ 0 cm)						
a) 1969/70	5	31	31	24	20	111
b) Maximal (langjahr.)	21	31	31	29	31	95
c) Minimal (langjahr.)	--	2	1	2	--	22
d) Mittel (langjährig)	4	14	21	17	10	61
2. Größte Neuschneehöhe innerhalb 24 Std. (cm)						
a) 1969/70	10	15	5	8	5	15
b) Maximal (langjahr.)	9	20	18	36	18	36
3. Monatliche Neuschneesummen (cm)						
a) 1969/70	16	50	11	59	25	161
b) Maximal (langjahr.)	19	30	39	82	39	154
c) Minimal (langjahr.)			12	5	--	44
d) Mittel (langjährig)	4	13	22	29	12	86,3
4. Eistage						
a) 1969/70	2	23	16	7	5	53
b) Mittel (langjährig)	3	11	14	8	3	39
5. Frosttage						
a) 1969/70	12	30	29	21	21	113
b) Mittel (langjährig)	16	25	26	23	18	108

6. Zahl der Tage mit Neuschneehöhen ≥	Snow depth in cm								Totals
	0	1	3	5	10	15	20	30	40	
a) 1969/70	25	24	11	11	4	1	-	-	-	25
b) Mittel (langjährig)	30	28	13	8	2	1	0,4	0,1		30

Commas indicate decimal points.

Key to Table 1:

1. Number of days with an unbroken snow cover (> 0 cm)
   a. 1969/70
   b. maximum (several years)
   c. minimum (several years)
   d. average (several years)
2. Maximum new snow depth within 24 hours (cm)
   a. 1969/70
   b. maximum (several years)
3. Monthly new snow totals (cm)
   a. 1969/70
   b. maximum (several years)
   c. minimum (several years)
   d. average (several years)
4. Days of ice
   a. 1969/70
   b. average (several years)
5. Days of frost
   a. 1969/70
   b. average (several years)
6. Number of days with new snow accumulation >
   a. 1969/70
   b. average (several years)

TABLE 2. WINTER STREET MAINTENANCE IN MUNICH
PERFORMANCE SURVEY 1969/70 AND 1968/69

	Day shifts		Maximum used per day	
	1969/70	1968/69	1969/70	1968/69
Snowplows (roads)	3592	1640	224	229
Snowplows (sidewalks)	1312	780	60	56
Snow propellers	10	35	2	4
Snow melters	29	21	2	1
Spreading equipment	2106	1055	39	33
Loading equipment	2025	738	83	45
Snow removal trucks	8054	4396	308	263
City labor	41,561	27,237	690	651
Private labor	31,958	28,648	978	1923
Consumption of salt, sand and gravel			32,690 t	10,100 t
Of which salt.....			28,250 t	6400 t
Approximate snow removal.....			500,000 m^3	200,000 m^3

TABLE 3. WINTER STREET MAINTENANCE 1969/70 IN MUNICH
UTILIZATION FACTORS FOR CLEARING AND SPREADING EQUIPMENT

Period	Theoretical utilization factors for Clearing equipment	Spreading equipment
11/26/1969-12/31/1969	21.8%	51.0%
January 1970	4.4%	36.4%
February 1970	19.7%	53.5%
3/1/1970-4/7/1970	6.3%	24.6%
Winter 1960/70	12.9%	40.6%

TABLE 4. WINTER STREET MAINTENANCE 1969/70 IN MUNICH
UTILIZATION FACTOR FREQUENCY FOR CLEARING AND SPREADING EQUIPMENT

Equipment utilization factor in winter 1969/70	On x% of the days between 11/26/69 and 4/7/70 Clearing equip. for	Spreading equip.
0%	100%	100%
10%	22,5%	73,0%
20%	19,5%	63,0%
30%	16,5%	51,0%
40%	13,5%	42,0%
50%	12,0%	36,7%
60%	9,0%	34,4%
70%	6,8%	30,7%
80%	3,8%	24,7%
90%	3,8%	9,7%

Commas indicate decimal points.

The following were used for each cm of daily new snow and for one million m^2 of area to be cleared

at more than 10 cm new snow
permanently 1.1 clearing vehicles,
at 6-10 cm new snow
1.3 to 2.6 i.M. 1.8 clearing vehicles,
at 3-5 cm new snow
1.4 to 3.8 i.M. 2.7 clearing vehicles.

A reasonable conclusion from this and from a cost comparison would be that when possible, salt spreading must replace mechanical clearing in light falls of new snow because of the repeated specific costs.

Surface Treatment

Within the framework of surface treatment, especially hazardous areas are covered by spreading gravel-sand mixtures or today primarily salt, and sidewalks by spreading sand or gravel. In addition all streets especially important for traffic flow and business are kept in a condition safe for

traffic by spreading salt. To a large extent salt is also used to support mechanical clearing for preventive purposes before expected snowfalls or slippery ice and after clearing snow to melt and soften ice and snow residue which has become more or less hard, as well as in place of mechanical snow clearing in sparse snowfalls.

Spreading equipment is more evenly and often better utilized compared to clearing equipment (Figure 1). During the 1969/70 winter the theoretical utilization factor was at least 40.6% (Table 3), and on 33 days, that is 24.7% of all the days of winter 1969/70, more than 80% of equipment was in use (Table 4). The basis for the better utilization of spreading equipment held in reserve lies in its greater versatility, and also in the relatively limited number of units, as measured by the size of the road system. A certain increase seems quite feasible under these circumstances.

Labor

The drawings in Figure 1 plotted concerning the labor used very clearly show the principal reasons for the difficulties which arise in heavier snowfalls. The amount of labor remains essentially the same, regardless of the snow depth and equipment utilization. Weekends and holidays can be distinguished by the short-term drop in the figures. In heavier snowfalls, additionally required labor can no longer be recruited for large-scale use. Work on sidewalks, crossings, stopping areas, the clearing of gutters, in short, all non-mechanisable operations, can only be executed superficially.

Snow Removal

The drawings plotted for vehicles used for snow removal show little order. Of particular note is the snow removal following snow clearing with, in some cases, considerable time delays. At first glance this seems incomprehensible and appears to be shortcoming. This finding is however, symptomatic for the uncertainty to which the snow removal pattern is always subject, because it can never be precisely enough predicted whether the easily removal operation will be shortly unnecessary due to an incipient thaw.

Winter Street Maintenance Costs

The services performed over the entire 1969/70 winter estimates at approximately 11,150,000 DM, corresponding to 5,575 DM/km (with approximately 2000 km of streets, including approximately 400 km with sidewalks on both sides) or 0.60 DM/m^2, had never previously risen to this level in Munich. Expenditures should be at the upper boundary of that which is still economically acceptable even in an extremely severe winter, and also in relation to the resources annually available for maintenance of the road system to the extent of approximately 10 million DM at present. Service performed in a 24-hour maximum, valued at approximately 437,031 DM, corresponds to a projected annual operating cost of approximately 120 million DM. Maximum winter road maintenance is thus in the short run more productive than operations on all large-scale traffic improvement construction projects

in Munich, if material costs are not considered. The planning necessary for winter street maintenance becomes clear, if we recall that construction operations of this magnitude can be planned weeks ahead and mostly start up gradually; winter maintenance operations starts up abruptly within 1 to 2 days and as quickly shut down. It is obvious that a large-scale operation of such irregularity cannot always run without problems everywhere.

6. Conclusions

If an attempt is made to critically evaluate urban winter street maintenance and to establish the limits of what is possible and feasible, we can ascertain:

The principal aim of urban winter street maintenance must be to sustain commercial intercourse at all times. Thus the main road system must have priority and all technical aids must be utilized. By combining preventive salt spreading -- mechanical clearing -- subsequent salt spreading and clearing residue as well as snow removal, this can be achieved at least to some degree of satisfaction by accepting high costs, in a new snowfall of up to 20 cm in 24 hours, inasmuch as the use of salt is still effective based on the temperature situation.

Compromises must (inevitably) be tolerated in a secondary road system. In light snowfalls side-streets parallel to main thoroughfares should be able to be cleared. In heavier snowfalls of more than 10 to 12 cm in 24 hours, the clearing of sidestreets must wait if possible in favor of priority treatment of main thoroughfares.

As before the problem clearing away snow with cars parked along the sides remains unsolved. Short-term posted parking restrictions, alternate side parking restrictions and all similar attempts have not previously proved to be entirely satisfactory.

The treatment of pedestrians crossings, required by the ruling within at most three hours after the advent of a dangerous situation, can hardly be executed anywhere by hand due to the absolutely unjustifiably large number of workers which must be kept ready for this eventuality. The only solution is the mechanized spreading of salt over a large area on roadways, including crossings, and at least in normal cases at not excessively low temperature the formation of icy patches can be prevented.

With the continuing deterioration of the personnel situation, the tasks to be carried out exclusively by hand can be performed less and less effectively. Without comprehensive further development of winter street maintenance technology, the implementation of winter street maintenance in cities and the implementation of statutory edicts may at least in some areas have been permanently impaired.