Traffic Volume Reductions Due to Winter Storm Conditions

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When hazardous driving conditions exist on roads, road users have less desire to travel. As a result of snow and icy conditions, a reduction in traffic movement occurs. The decrease in traffic movement is almost unexamined so far. During a research project conducted in 1991–1992 to study the impact of snow and ice control operations on traffic accident rates, the need for estimating the decrease in traffic movement urged such calculations. The reductions in traffic volumes generated as a result of adverse snow and icy conditions were measured, grouped, and correlated during various weather conditions in four states (Illinois, Minnesota, New York, and Wisconsin). Traffic volumes reductions factors during different winter storms conditions were calculated and reported.

During winter, snow and ice storms cause emergency conditions that disturb the normal activities of any community. Effects can range from minor disruptions to major catastrophes that shut down industries, knock out energy and communication lines, and make streets, roads, and highways impassable. Achieving normal conditions as soon as possible depends on the technology used for snow and ice removal, the proper planning and management of snow and ice removal, and the programs and policy for effective use of all available resources. The maximum-benefit policy for dealing with snow and ice problems would be to achieve "bare pavement" (i.e., no accumulation of snow and ice on all streets, roads, and highways) as quickly as possible and without having any adverse side effects. To the other extreme, the minimum-benefit policy is that of no response to snow removal at all. To select a policy between these two extremes, policy makers must decide what goal will be sought to reduce the hazardous driving conditions and impaired mobility (*1*).

During hazardous driving conditions, a reduction in traffic movement occurs; travelers have less desire to travel. The interaction between people (road users) and space (roads) has been studied by economists, demographers, sociologists, planners, and others (*1*). Many factors affect these movements or interactions and can be categorized as follows:

1. A generating factor related to individual trip makers and their willingness to travel,
2. An attraction factor related to the importance (or utility) of the particular destination,
3. A linkage factor related to the difficulty (or cost) of moving from the origin to the destination, and
4. Other related factors.

The behavior of road users relates mainly to the descriptions and understanding of how, and in response to what, they believe in regard to travel. For example, one economic theory of travel behavior considers most travel to be an intermediate good that must be consumed at some monetary and psychological cost to the traveler in order to derive equal or greater benefits in kind from activities indulged in at the trip destination. The response of road users to travel cost and destination choices varies according to the characteristics of the behaviors and beliefs of the travelers.

METHODOLOGY

Traffic volume studies are made to obtain and collect data on the number of vehicles that pass a point on a highway section during a specified period. Normal traffic volume counts are usually measured under dry road conditions. A continuous traffic volume count at a road section will show the variation of traffic volume from time to time. Previous studies proved that this variation is repetitive and rhythmic.

Data Collection

Eleven automatic traffic recorders (ATRs) in operation during various weather conditions on 11 highways outside urban areas were selected randomly with the cooperation of authorities in four states: Illinois (Ogle and Lee counties), Minnesota (Olmsted County), New York (Wayne, Monroe, Steuben, and Onondaga counties), and Wisconsin (Walworth, Kenosha, and Waukesha counties). Table 1 presents all the 11 ATRs used in this study.

Data from all 11 ATRs during the first 3 months of 1991 were collected. Furthermore, additional data from Wisconsin (December 1990) and New York State (December 1989 and January, February, March, and December, 1990) were collected and included in the analysis.

During snowstorms, a reduction in traffic volume occurs. The reduction is a function of time of day, type of highway, normal traffic volumes, level of service, weather conditions, road user behavior and satisfaction, and other factors.

The data collected for this study are given in the following paragraphs.

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TABLE 1 Automated Continuous Count Stations

State	County	Highway	Station#	Location
NewYork	Wayne	STH 104	3732	0.9 Mile E. of RT 14 (Sodus Bay)
NewYork	Monroe	STH 590	4342	0.6 Mile N. of RT 286 (Seabreeze)
NewYork	Onondaga	I - 81	3311	0.8 Mi. N. of Cortland-Onondaga C.L.
NewYork	Steuben	STH 17	6441	NE of S. JCT. of RT 415
Wisconsin	Walworth	USH 12	64-0002	Lake Geneva
Wisconsin	Kenosha	STH 50	30-6109	0.2 Mile W. of USH 45 (Salem)
Wisconsin	Waukesha	I - 43	67-0010	Crowbar RD overpass (Crowbar)
Minnesota	Olmsted	TH 14	212	E. CR 104 Rochester
Minnesota	Olmsted	TH 52	188	S. of ORONOCO
Illinois	Ogle	I - 39	205	S. of CH 20 (Lindenwood)
Illinois	Lee	Ill 38	280	W. of Ashton

Highway Characteristics

To study the reduction in traffic volumes during snow and icy conditions, it is useful, practical, and desirable to know the characteristics of the testing locations (Table 2). The locations used in this study were selected randomly for each jurisdiction area chosen earlier for another research project (*2*); no specific preconditions were set for the selection.

Traffic Volumes

In this study the latest annual average daily traffic and the actual 24-hr counts during each testing period and for each testing location were measured continuously and provided by the authorities in each of the participating states. These counts were used as the base from which to calculate the variations in traffic volumes.

Level of Service

The maximum-benefit policy for dealing with snow and ice problems would be to achieve bare pavement as quickly as possible. The optimum snow and ice policy varied from one participating area to another, but they were all similar in establishing bare pavement as soon as possible. Reducing the level of effort for snow and ice removal and control has immediate consequences on delay, traffic volume, traffic congestion, and public image of the state department of transportation.

Climatic Data

All participating highway agencies responsible for winter road maintenance have been using weather forecasting to aid preparation efforts before a storm begins. For this paper, the following climatic data for each participating area during the study period were collected:

1. Storm period (start and end time: hour, day, and date),
2. Temperature range (high and low), and
3. Depth and type of snow (dry, wet, sleet, etc.).

Climatic data were also derived from the basic data files at the National Climatic Data Center in Asheville, North Carolina, through its monthly report for each state.

Analysis

The approach used in this study to measure reductions in traffic volume during any snowstorm depends mainly on the traffic counts of the ATRs presented in Table 1 and the following.

TABLE 2 General Characteristics of Testing Sections

Rural & Suburban Highways	Rural & Suburban Freeways
- Average lane width of about 3.5 meters. - Few restriction to through traffic by traffic control devices - Average shoulder width of about 2 meters. - Mostly level terrain - Average speed limit of 72-88 kilometer/hr.	- Average lane width of about 4 meters. - Divided highways with 2 - 3 lanes per direction - Average shoulder width of about 3 meters. - Mostly level terrain - Average speed limit of 88-105 km/hr.

Traffic Counts

All traffic counts for all snowstorms were categorized and grouped by

1. Normal average daily traffic (ADT) volume. Each ATR was categorized under one of the following ranges on the basis of its normal ADT:
   –Rural and suburban freeways: 11,000 to 20,000, and 21,000 to 30,000.
   –Rural and suburban highways: 3,000 to 6,000, and 7,000 to 10,000.
2. Day of week. The day of occurrence of each snowstorm was categorized by weekday (Monday through Friday) or weekend (Saturday or Sunday).
3. Snow precipitation. Each snowstorm was categorized by snow precipitation and temperature range.

Hourly Traffic Volume

For every snowstorm, the hourly traffic volume was measured at the ATR station location and compared to the normal hourly traffic count for the same location during a similar day, and at the same hour, month, and year. From the comparison, hourly reduction factors were derived during each snowstorm. Table 3 presents an example of the hourly traffic volume reduction factors derived during a storm in Wayne County, New York. Similar derivations were made for the traffic volumes for all the other snowstorms in all tested locations. Figures 1 through 4 show two examples of a graphical presentation of hourly traffic reduction percentages during a snowstorm in Wayne County, New York.

Peak Periods

Each similar snowstorm event was divided into hourly periods:

1. Peak-hour periods
   –Weekdays (morning and evening)
   –Weekends (variable)
2. Off-peak-hour periods
   –Early morning
   –Midday
   –Late evening

TABLE 3 Example of Calculating Hourly Traffic Volume Reductions During Storm in Wayne County

State: New York **County:** Wayne **Highway:** STH 104
AADT = 6750 **Station Number** = 3732

Date: February 13-14, 1991 **Snowfall** = 25 mm **Temperature range** = -8 to -4 °C
Snow storm period: (23.00) 2 /13 /91 (to) (23.00) 2 /14 /91

Hr.	Normal Vol.	Wednesday (2 / 13 / 91)		Thursday (2 / 14 / 91)	
		Snow Vol.	Factor	Snow Vol.	Factor
- 1	75	77	1.02	73	0.97
- 2	34	36	1.05	26	0.75
- 3	35	35	1.01	34	0.96
- 4	26	27	1.02	20	0.75
- 5	44	45	1.03	36	0.81
- 6	83	84	1.01	80	0.96
- 7	168	177	1.05	155	0.92
- 8	335	342	1.02	325	0.97
- 9	321	305	0.95	276	0.86
- 10	299	290	0.97	284	0.95
- 11	275	269	0.98	240	0.87
- 12	285	285	1.00	248	0.87
- 13	256	228	0.89	246	0.96
- 14	281	283	1.01	293	1.04
- 15	301	313	1.04	271	0.90
- 16	445	427	0.96	436	0.98
- 17	520	520	1.00	536	1.03
- 18	448	439	0.98	444	0.99
- 19	312	312	1.00	272	0.87
- 20	172	174	1.01	148	0.86
- 21	153	153	1.00	126	0.82
- 22	96	85	0.89	90	0.93
- 23	97	86	0.88	94	0.97
- 24	94	90	0.95	103	1.09
	5155	5082	avg. = 0.99	4856	avge. = 0.94

(1) Snow Reduction Factor = (Snow Vol.) / (Normal Vol.) in relative time (hour)

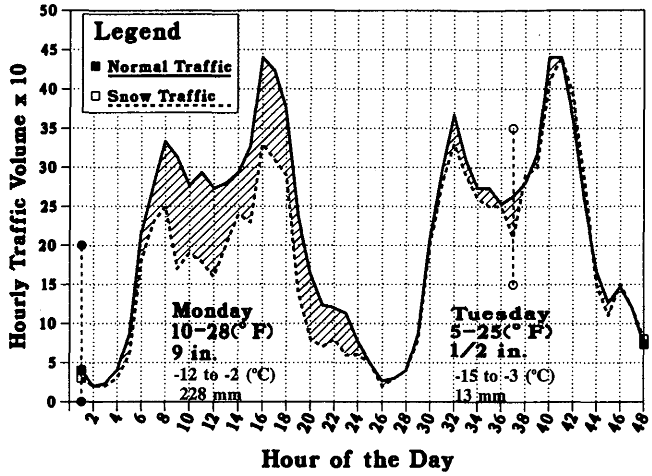

FIGURE 1 Example of traffic behavior at continuous count station in Wayne County during winter snowstorm, Thursday and Friday.

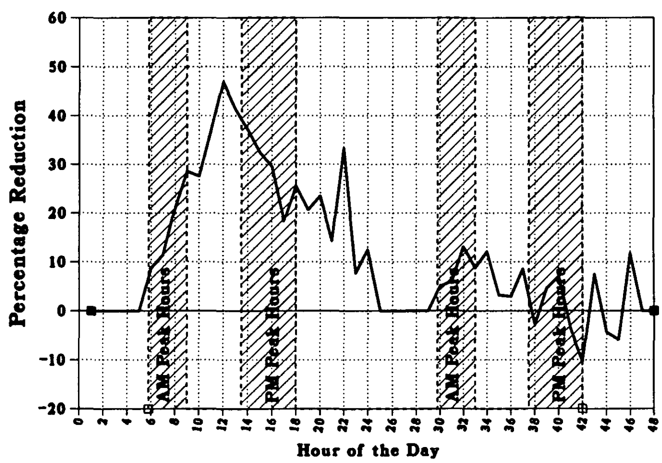

FIGURE 2 Hourly traffic volume reduction for Figure 1.

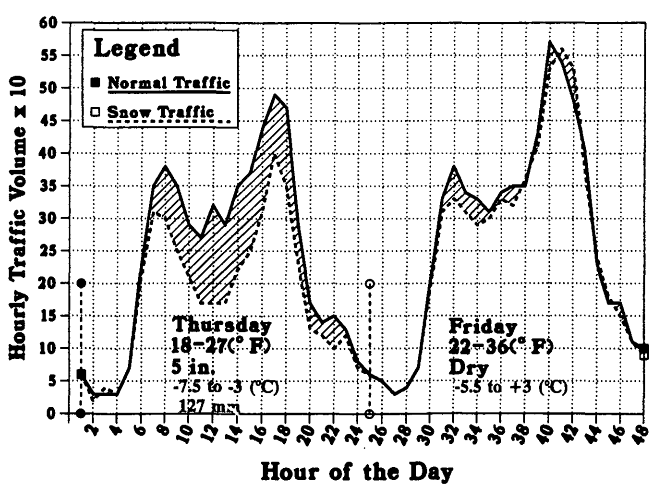

FIGURE 3 Example of traffic behavior at continuous count station in Wayne County during winter snowstorm, Monday and Tuesday.

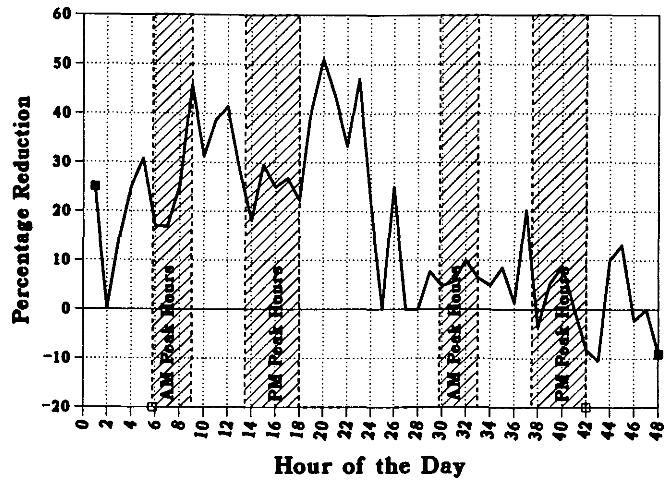

FIGURE 4 Hourly traffic volume reduction for Figure 3.

Traffic Volume Reductions

All traffic volume reductions under the same categorized group were compiled and correlated, and an average reduction was calculated by dividing the sum of hourly reductions by the sum of their respective hourly normal volumes for each compiled categorized group.

RESULTS

For this study, the analysis covered the traffic volumes on highways and freeways outside urban areas in four states (see Table 1). All participating areas in this study had a similar snow and ice control policy to establish bare pavement as soon as possible. The results of the analysis are summarized, given in Table 4, and illustrated in Figures 5 and 6.

CONCLUSIONS

Conclusion One

The average reduction in traffic volume due to winter storm conditions depends directly on weather conditions (the more severe the winter storm, the greater reduction in traffic volume):

- Winter storms with snow precipitation of less than 25 mm have an average traffic volume reduction of 7 to 17 percent during weekdays and 19 to 31 percent during weekends.
- Winter storms with snow precipitation of 25 to 75 mm have an average traffic volume reduction of 11 to 25 percent during weekdays and 30 to 41 percent during weekends.
- Winter storms with snow precipitation of 75 to 150 mm have an average traffic volume reduction of 18 to 43 percent during weekdays and 39 to 47 percent during weekends.
- Winter storms with snow precipitation of 150 to 225 mm have an average traffic volume reduction of 35 to 49 percent during weekdays and 41 to 51 percent during weekends.
- Winter storms with snow precipitation of 225 to 375 mm have an average traffic volume reduction of 41 to 53 percent during weekdays and 44 to 56 percent during weekends.

TABLE 4 Average Traffic Volume Reductions per Average Snow Precipitation per Time of Day per Day of Week

Snow (mm)	Time of Day	Average Traffic Reductions (%) (a)	(b)	(c)	(d)	Range
< 25	1	8	10	11	12	8-12
	2	7	8	9	10	7-10
	3	12	15	16	17	12-17
	4	7	8	9	11	7-11
	5	11	12	13	13	11-13
	6	27	29	31	31	27-31
	7	23	23	21	19	19-23
25-75	1	14	16	21	23	14-23
	2	11	13	17	18	11-18
	3	13	15	22	25	13-25
	4	12	12	14	15	12-15
	5	23	25	28	31	23-31
	6	32	35	38	41	32-41
	7	30	32	35	36	30-36
75-150	1	28	30	31	31	28-31
	2	18	20	19	21	18-21
	3	36	38	38	39	36-39
	4	21	23	25	25	21-25
	5	40	42	43	43	40-43
	6	42	43	45	47	42-47
	7	39	41	41	42	39-42
150-225	1	43	44	45	45	43-45
	2	36	37	38	39	36-39
	3	42	44	44	46	42-46
	4	35	37	38	40	35-40
	5	47	48	49	49	47-49
	6	49	50	50	51	49-51
	7	41	42	44	46	41-46
225-375	1	52	53	51	52	51-53
	2	42	42	41	41	41-42
	3	47	49	48	49	47-49
	4	42	43	43	44	42-44
	5	50	49	51	51	49-51
	6	55	56	55	55	55-56
	7	44	47	48	50	44-50

Rural & Suburb:

- Freeways:
(a)11,000-20,000
(b)21,000-30,000

- Highways:
(c) 3,000- 6,000
(d) 7,000-10,000

Temperature Range:

-13°C to +10°C

Weekdays (Monday - Friday):

(1) Off-Peak Hours (Early AM)
(2) AM Peak Hours
(3) Off-Peak Hours (Mid-Day)
(4) PM Peak Hours
(5) Off-Peak Hours (Late PM)

Weekends (Saturday+Sunday):

(6) Off-Peak Hours (Variable)
(7) Peak Hours (Variable)

*** Holidays and days with special events are not included in this study.**

Conclusion Two

The average reduction in traffic volume due to winter storm conditions is inversely related to the importance of traveler destination and the traveler's willingness to travel.

- The average reduction in traffic volume during weekday peak hours (mostly work and other necessary trips) was less than during weekday off-peak hours (mostly discretionary trips).
- The average reduction in traffic volume during weekday hours was less than during weekend hours.
- The average reduction in traffic volume during weekend peak hours (most likely necessary trips) was less than during weekend off-peak hours (mostly discretionary trips).

Conclusion Three

The influence of both the generating factor (individual trip maker and his or her willingness to travel) and the attraction

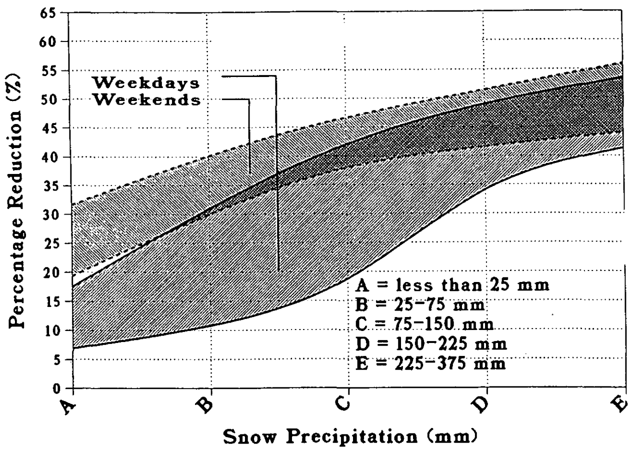

FIGURE 5 Range of traffic volume reduction, weekdays versus weekends.

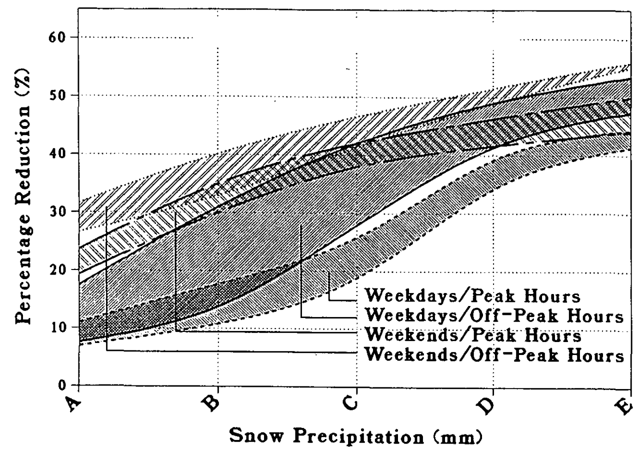

FIGURE 6 Range of traffic volume reduction, peak versus off-peak hours.

factor (importance of the particular destination) on traffic volume reductions is directly related to the severity of winter storms.

- Winter storms with snow precipitation of less than 25 mm have an overlap in the ranges of peak (mostly necessary trips) and off-peak (mostly discretionary trips) average traffic volume reductions.
  - –The average reduction in peak-hour traffic on weekdays ranged from 7 to 11 percent.
  - –The average reduction in off-peak traffic on weekdays ranged from 8 to 17 percent.
- Winter storms with snow precipitation of 225 to 375 mm have more of a separated range of peak and off-peak average traffic volumes reductions.
  - –The average reduction in peak-hour traffic on weekdays ranged from 41 to 44 percent.
  - –The average reduction in off-peak-hour traffic on weekdays ranged from 47 to 53 percent.

Conclusion Four

The range of average reductions in traffic volume during severe winter conditions depends directly on the difficulty and safety of moving from the origin to the destination (linkage factor).

Road users during weekday off-peak hours are more decisive in making or not making a trip when weather severity is low (less than 50 mm) or high (more than 200 mm); and less decisive in making or not making a trip when weather severity is average (between 50 and 200 mm). The range's width of traffic volume reduction is smaller at less than 50 mm or greater than 200 mm than the range's width at less than 200 mm and greater than 50 mm (Figures 5 and 6).

Road users during weekend off-peak hours are more decisive in making or not making a trip as weather severity increases. The range's width of traffic volume reduction decreases as winter severity increases.

Road users during weekday or weekend peak hours are more consistent and decisive in making or not making a trip independent of weather severity. The range's width of traffic volume reduction is mostly constant at different snow and icy conditions.

ACKNOWLEDGMENTS

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