MANAGEMENT SCIENCE
Vol. 20, No. 2, October, 1973
Printed in U.S.A.

THE POLITICAL PROPERTIES OF CRYSTALLINE H_2O: PLANNING FOR SNOW EMERGENCIES IN NEW YORK*

E. S. SAVAS†

Columbia University

A major snowstorm produced a serious snow emergency and a political crisis in New York City. Mayor Lindsay asked for an analysis of the problem to prevent its recurrence. His management science unit studied four basic questions: (1) How much snow falls on New York City? (2) How much work has to be done to clean it up? (3) What is the capacity for performing this work? (4) What improvements are needed to correct any imbalance between work load and work capacity?

The surprising findings eliminated most of the remedies that had been offered earlier. A low-cost snow emergency plan was prepared, calling for some additional equipment, better deployment, and a strategy for more rapid mobilization. The recommendations were implemented promptly, and with due regard for political impact, in the midst of a mayoralty election campaign.

It was on Sunday, February 9, 1969, that a malevolent god of weather deposited a goodly amount of snow upon New York City. This in spite of repeated forecasts by the official U.S. weather seers that nothing of the sort was going to happen. By the time the Department of Sanitation realized that the city was in for a real humdinger and called in additional men to augment its skeletal Sunday work force, many men could not reach their work stations because traffic arteries were impassable and public transit was reduced to spasmodic operation. Those who managed to report to work found that their equipment frequently could not cope with the deep drifts that had accumulated, and broke down. Or, they looked back on their freshly plowed swath and watched the wind undo their work. Others could not proceed because abandoned cars blocked their paths. Some succeeded in finishing their plowing assignments, only to discover later that what they had plowed turned out to be an isolated street segment because the abutting, complementary plow routes fore and aft of their stretch, lying within adjacent districts, could not be completed.

Late Sunday the city was a winter wonderland. Families tumbled out of the canyons and frolicked together in the snow, while some skiers were sighted ostentatiously poling along the truly Great White Way. By mid-week however, with only scant progress evident in the mammoth task of clearing away the snow, the brief holiday mood had long since given way to denunciations by assorted politicians, labor leaders, businessmen, and a high United Nations' official, complaints from the public, critical editorials, calls for resignations, City Council hearings—and loud, prolonged jeering with pointed, indelicate suggestions during a visit to Queens—all directed at Mayor John V. Lindsay. In particular, many self-professed "little people" living in the "outer boroughs" of Queens, Brooklyn, The Bronx, and Staten Island resented what they felt was an undue concentration on cleaning up the snow in Manhattan, where the sophisticated smart set is reputed to live, while Mayor Lindsay, as usual in their eyes, ignored them and their simple, middle-class needs in favor of the rest of the city. That the mayoral elec-

* Received March 1973.

† The author is indebted to Stephen R. Rosenthal and Helen Underhill for their assistance in this project, which was completed while the author was First Deputy City Administrator in the Office of the Mayor of the City of New York. The cooperation of the Department of Sanitation is also acknowledged.

tion later in the year would afford a splended opportunity for retribution did not entirely escape the attention of the Mayor's angry critics.

Every special interest group had its own diagnosis of the problem and its own preferred solution. Surprisingly enough, each solution that was offered usually meant more money for the offerer. For example, one proffered solution was to have more sanitation workers on duty around the clock during the winter, at overtime rates. Another was to buy more snow-removal equipment. Yet another was to hire more mechanics to maintain the existing equipment. Still another was to allow sanitation workers to report for snow-removal duty wherever they found it convenient, presumably near their homes. Finally, owners of large bulldozers thought that the problem would be substantially alleviated if the City would merely agree to pay usurious rates to hire their equipment during snow emergencies.

It was in such harried, emotional, and politically charged circumstances, eight days after the storm, that Mayor Lindsay directed the systems analysis unit in his office to undertake a thorough study of the city's snow-fighting capability. The analysts pounced upon the problem like dogs presented with a choice T-bone steak, delighted at the opportunity to gnaw on such a fresh and meaty morsel.

The analysis was not to be an inquisition to find a culprit or a scapegoat. Its objective was to find out what went wrong and to prevent its recurrence. Realistically, the project could not be expected to produce meaningful results soon enough to be useful during the remaining few weeks of the current snow season. In fact, Deputy Mayor Timothy W. Costello, to whom the unit reported, cautioned them against excessive enthusiasm and subsequent disappointment by suggesting that it would be a warm day in New York when the study was finished, with interest in the problem having melted away with the snows of yesteryear.

Structuring the Problem

A review of the literature ([9], [10], [11], [12], [15]) and a survey of practices in other cities ([1], [2], [3], [4], [5], [8]), together with an examination of the written procedures in New York City ([6], [7]) proved generally informative but failed to provide a methodology suitable for the task at hand. Accordingly, it was necessary to create an original approach to the problem and after some initial groping the effort gradually crystallized about four fundamental, strategic questions:

(1) How much snow falls on New York City?

(2) How much work has to be done to clean it up?

(3) What is the City's capacity for performing this work?

(4) What improvements are needed to eliminate any imbalances between work load and work capacity?

How Much Snow Falls on New York?

To answer the first question required a methodical search of U.S. Weather Bureau records back to 1910, which revealed that a storm matching or exceeding the February storm's depth of fifteen inches occurs once in twelve years, on the average. This means that such a storm will occur "at the wrong time"—i.e., when only a minimal (Sunday) force is on duty—once in 84 years, and, if the weather forecasters are credited with merely 50% accuracy, such an unfortunate episode will occur "unexpectedly and at the wrong time" no more than once in 168 years, on the average. (To spin this out further, the better part of a millennium is likely to pass before a recurrence in an election year!) When the analysts presented the statistics, with the wry remark that we were fortunate

to have observed such a rare event during our lifetimes, Mayor Lindsay, to his credit, mustered a wan smile.

More constructively, inspection of snow records disclosed that:

(a) Snowfall in New York City averages 33″ annually.

(b) An average season has 2 storms greater than four inches (see Fig. 1).

(c) An average season has 6 or 7 snowstorms of an inch or more (see Fig. 2).

(d) The rate of accumulation of snow during a snowstorm was as high as 10.4″ in eight hours, as shown in Table 1.

How Much Work Has to be Done?

Coping with a snowstorm in New York involves up to three sequential activities: spreading salt, plowing, and hauling away snow. Spreading salt, which is done by special-purpose vehicles, is the routine, first line of defense and is usually done perhaps twelve times a year; that is, not only for the six or seven snowfalls which turn out to be greater than one inch, but also for others which appear threatening but ultimately deposit less than an inch, and for freezing rain. Plowing is done three or four times an average year, as depths approach four inches or so. (Specific decisions about plowing will depend on such factors as current ground temperature, predicted air temperature, wind and traffic conditions—because spreading salt is more effective for melting snow when traffic is relatively heavy.) Removal of snow by hauling is relatively rare, being reserved generally for snowfalls greater than six inches when the temperature is expected to remain below freezing for an appreciable period of time. The study [16] addressed all three activities—spreading, plowing, and hauling—but only the first two will be discussed here.

The data on snowfalls, and the work activity dictated in response to snow, confirm that a comprehensive snow plan is necessary, for it will be exercised about a dozen times a year even though incapacitating storms, such as the one which triggered the project, are quite rare.

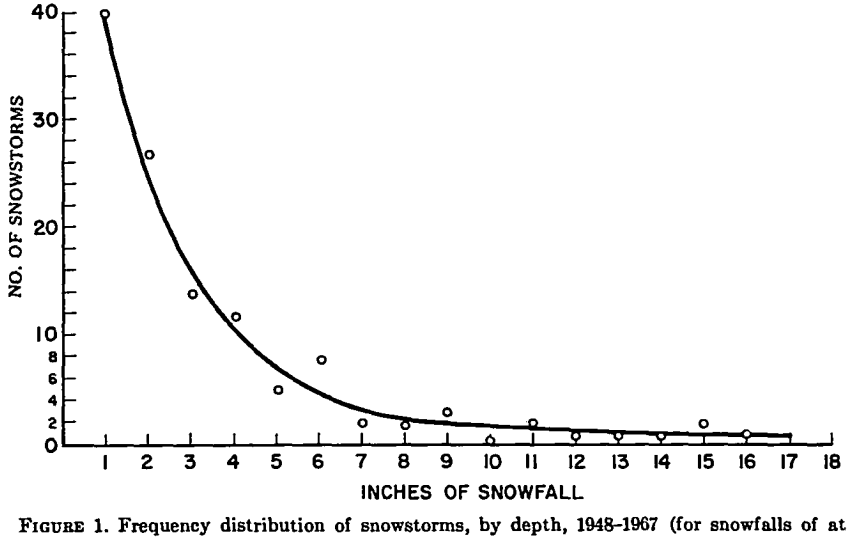

FIGURE 1. Frequency distribution of snowstorms, by depth, 1948–1967 (for snowfalls of at least one inch).

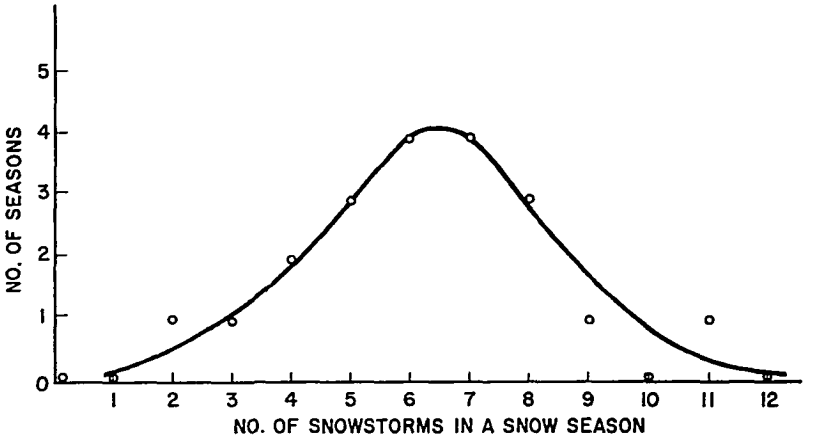

FIGURE 2. Frequency distribution of snow seasons by number of snowstorms, 1948–1967 (for snowfalls of at least one inch).

TABLE 1

Peak Accumulation Rates for Snowfalls[1]

A. *Average Accumulation During the Peak Period of Indicated Duration*[2]

Final Depth	No. of Storms	1 hr.	2 hrs.	3 hrs.	4 hrs.	5 hrs.	6 hrs.	7 hrs.	8 hrs.
4″-9″	14	1.0″	1.7″	2.4″	2.9″	3.3″	3.6″	4.0″	4.3″
9″+	9	1.7″	2.9″	3.9″	4.8″	5.6″	6.3″	6.9″	7.4″

B. *Maximum Accumulation During the Peak Period of Indicated Duration*[3]

4″-9″	1	1.4″	2.6″	3.3″	4.2″	4.7″	5.2″	5.5″	5.6″
9″+	1	2.5″	4.1″	5.4″	6.7″	7.6″	8.6″	9.5″	10.4″

[1] Based on the 23 storms greater than or equal to four inches during the period 1958–1967.

[2] For example, if one looks at the 3-hour period of heaviest snowfall for each of the 14 storms whose final depth was 4″-9″, the average accumulation during those 3-hour periods was 2.4″.

[3] For example, the greatest 5-hour accumulation for any storm was 7.6″; this occurred for a storm whose final depth was greater than 9″.

To determine the amount of cleanup work called for by a snowstorm, it was necessary to analyze the street system. The Department of Sanitation, which is responsible for snow removal, divides the streets into three priority classes, primary, secondary and tertiary, corresponding to the relative importance of the streets. (See Exhibit A in Savas [16] for definitions.) As shown in Table 2A, primary streets comprised 43 % of the linear street mileage, but 45 % of the spreader miles, and 53 % of the plow miles in the city. (Depending on the width of the street, a vehicle may have to traverse it more than once in order to salt it or plow it, while spreaders and plows have different effective widths.) Clearly, a ranking system which was so undiscriminating as to assign more than half the total plowing work an equally high priority left something to be desired.

TABLE 2

Street Mileage

A. *Existing Street Network*

Class of Street	Linear Miles		Spreader Miles		Plow Miles	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Primary	2530	43	2733	45	6755	53
Secondary	1978	34	1978	33	3500	28
Tertiary	1331	23	1331	22	2444	19
Total	5839	100	6042	100	12,699	100

B. *Recommended Street Network*

Primary						
Emergency	1600	27	1730	28	4272	33
Other	930	16	1003	17	2483	20
Secondary	1978	34	1978	33	3500	28
Tertiary	1331	23	1331	22	2444	19
Total	5839	100	6042	100	12,699	100

There did exist within the primary streets a category labeled Snow Emergency Streets, which totaled only 428 miles, some 7% of the total street mileage. However, this distinction was not used in actual operations, and furthermore an inquiry concluded that much of this street network was originally devised as the best way to flee the city in the event of a nuclear holocaust, rather than as a network which, if cleared, would enable the city to function adequately after a major snowfall. Therefore, a new high-priority network was designed during this study; it included all parkways and bus routes, and the streets which connect hospitals, police stations, fire houses, bus garages, and fuel depots to those arteries. It represents 1,600 linear miles, or 33% of the city's total plow miles. Clearing these streets represents the minimum work that has to be done to permit the city to function during a snow emergency. Table 2B defines the work load, in terms of the number of miles to be covered, given a policy determination that only primary, or primary and secondary, or all streets are to be cleared.

What is the Capacity for Performing This Work?

In order to estimate the city's capacity for snow removal work, it was necessary to look at the type, amount, and productivity of equipment.

The principal snow fighting equipment consists of spreaders and plows, for which a conservatively high down-time figure of 40% was assumed in the analysis; that is, it was assumed that 40% of the spreaders and plows would be out of commission, so that only 134 spreaders and 1,050 plows would be available for work. (Actual down time was on the order of 30 to 35%.) Productive time was estimated by making allowance for meal time, rest breaks, refueling time, travel time to and from routes, etc., and from this it was concluded that about 12 hours of productive time on the route is available during the two-shift, 22-hour winter work day. Furthermore, it was assumed

TABLE 3
Plowing Capability

	Snow Emergency Streets	All Primary Streets	Primary and Secondary Streets	All Streets
Plow miles	4,272	6,755	10,255	12,699
Max. hrs. to plow	2.75	3.65	4.85	5.70
Avg. peak accumulation*	3.7″	4.5″	5.5″	6.1″
Max. peak accumulation*	5.0″	6.3″	7.5″	8.3″

* Derived from Table 1, for storms greater than 9″ for the indicated "Max hrs. to plow."

that up to 1.25 hours would be needed to start up and reach the beginning of a route. Finally, an extremely conservative figure of only 5 mph was assumed for the vehicles while on their routes. (This is the average auto speed in mid-Manhattan at noon on weekdays; plow speeds at midnight in Staten Island are obviously much higher.)

Putting together all these productivity figures and the street mileages leads to the striking conclusion that there is sufficient equipment available, in the aggregate, to plow *every* mile of *every* street in the city in only six hours, and to plow the high-priority streets in less than two hours! Based on the snow-accumulation rates of Table 1, and the above productivity estimates, Table 3 is derived. Recognizing that plows can work in depths up to about eight inches, it can confidently be concluded that the high-priority network can "always" be kept plowed. That is, the plowing force can "always" complete plowing those streets well before eight inches of snow would accumulate, and they could keep those streets open during the remainder of "any" snowstorm by repeatedly traversing those routes.

A corresponding analysis [16] shows that the salt-spreading capability was inadequate, for it would take seven hours to spread salt on all primary streets, during which time (see Table 1) 9.5″ has been observed to accumulate and the spreaders would therefore be unable to complete their work. Additional spreaders are needed in order to assert with confidence that the high-priority streets could "always" be salted before the snow becomes too deep for the spreaders to negotiate.

From the foregoing analysis of work loads and equipment capability, and contrary to some of the touted "solutions", the inexorable conclusion was that aside from additional spreaders, neither more plows nor improved maintenance was necessary; the plowing problem lay elsewhere. Indeed, if the available equipment could, in principle, plow the entire street network so quickly, where was the problem?

What Improvements are Needed?

The answer was to be found in the geographic deployment of equipment and the rate of mobilization of manpower to man the equipment.

The matter of equipment deployment is an interesting one. Most of the plowing vehicles are simply refuse-collection trucks fitted with plows. The trucks may have been satisfactorily distributed throughout the boroughs for their primary function, collection, but they were not properly distributed for plowing. (See Table 4.) The reason is obvious: a one-mile street segment in a bucolic area of Richmond will generate much less refuse than will a one-mile street segment in densely populated Manhattan, but it will have just as much snow to be plowed. In other words the public, without benefit of systems analysis, perceived the situation quite correctly: Manhattan did

TABLE 4

Geographical Deployment of Plows in Relation to Need

Area	Plow-Miles of Primary Streets	Distribution of Plows
	(%)	(%)
Manhattan West	8.6	9.2
Manhattan East	6.5	10.7
Bronx West	6.6	8.9
Bronx East	9.9	8.4
Brooklyn West	9.6	11.0
Brooklyn North	7.5	11.5
Brooklyn East	6.8	9.8
Queens West	14.7	12.8
Queens East	20.8	13.5
Richmond	9.2	4.0
Total	100.2%	99.8%

indeed receive better snowcleaning service. But this was a direct, technical consequence of Manhattan's high population density rather than a deliberate decision to withhold services from the other boroughs.

In order to satisfy these widely differing needs, for refuse collection and for plowing, one is faced with the necessity of providing two widely differing truck-allocation patterns. This dilemma was ultimately resolved by taking advantage of vehicles such as flushers, on which plows can be mounted. During the winter, when these see little use for flushing, they are to be relocated in such a way that, together with its normal complement of refuse-collection trucks, each borough will have a plowing capability proportional to the number of plow miles of high-priority streets in that borough. The few remaining disparities can be eliminated by directing certain truck-rich areas to send the desired number of trucks to certain truck-poor areas at the start of a snowstorm. This final distribution is designed to equalize the time it takes for each borough to clean its high-priority streets.

In a completely analogous way, the spreaders were shown (16) to be distributed inappropriately, leading to disparities between areas of up to 3:1 in the amount of time needed to spread salt on their primary streets. Because spreaders are single-purpose vehicles, unlike plows. it was possible to deploy them in such a way as to equalize spreading time for all areas of the city. (It should be noted that reported productivity differences between different parts of the city were used to "fine tune" the recommended deployment of plows and spreaders; however, because of reporting uncertainties, the allocation ultimately was made based on the distribution of plow-miles and spreader-miles among areas.)

Another finding worth noting concerns the distance between garages and the plow routes. In deriving Table 3, a startup delay of 1.25 hours was allowed as a conservative city-wide average. Again, however, looking at geographic variations proved useful, for in eastern Queens the travel time from the garage to the routes was as much as two or three hours during a snowstorm. This study confirmed the previously perceived need for a new garage in that area, and it was eventually acquired and put into operation.

Given sufficient equipment properly allocated throughout the city, with a rational set of priorities for work assignments, the only remaining need is for a good mobiliza-

tion plan, i.e., a plan which provides the right number of workers at the right place and at the right time.

Ordinarily, the more than 9,000 uniformed members of the Department's work force are easily sufficient to man all the snow equipment. However, manpower mobilization was a problem on Sunday, when for a 24-hour period the field force was insufficient to man even the full complement of spreaders, let alone any plows. Now this staffing problem can easily be solved with money. More men could be assigned routinely to Sunday duty or called up on short notice and at premium rates. In fact, two weeks after this famous storm, when another storm threatened and no one was taking any chances, the city spent one-third of a million dollars mobilizing and not a flake fell. The issue was how to provide, in effect, low-cost insurance against a serious snow emergency. The solution was to devise operating procedures which would increase the rate of mobilization and thereby decrease the elapsed time needed to have an adequate number of men and machines out on the streets.

This was accomplished by mounting plows on one fifth of the trucks just before winter weekends. By doing this in advance, a critical time advantage is gained for it takes almost two man-hours to prepare a truck in this way. In addition, some of the spreaders are loaded with salt just prior to winter weekends, even though unused salt will have to be unloaded on Monday to prevent caking and flat tires. Finally, in cooperation with the union, a special Sunday roster was developed, a snow emergency force which had agreed to respond to a telephone callup and to report promptly to their assigned posts. This agreement was encouraged by making more attractive arrangements for compensatory time off.

Implementation

The analysis was completed in June and then presented to Mayor Lindsay. By that time the mayoral campaign was in full swing and it was clear that the snow of February was gone but not forgotten; it had become a very lively campaign issue, with many candidates emphasizing it in speeches and in their TV advertisements.

In this environment, implementing the recommendations proved relatively easy; for once, a management science unit was in the right place at the right time with the right answers to an important problem—and without even a written report in hand.

The word went forth to put the findings into practice promptly, viz., before election day in November.

Week-long work sessions and regular reviews with the Commissioner and the Mayor's assistant gradually generated modifications, improvements, unanimous acceptance, budget alterations—and visible changes. Finally, the effort culminated in the preparation of a detailed briefing report, for issuance at a major press conference. The process of writing this press release was itself salutary, for it served to crystallize some hitherto unresolved areas, and clear up some lingering ambiguities. The final document described quite specifically the changes and improvements made in the city's snow-fighting tactics since the disastrous snowstorm, as evidence that the administration had learned from its experiences and that the problems would not recur. This candor was in keeping with the dominant motif of the mayoral campaign, the theme of chastened wisdom gained from experience in the second toughest job in America.

Near the start of the next snow season, just a few weeks before election day, a major press conference was held—at the famous corner in Queens where there was much ado nine months earlier. Mayor Lindsay announced the various changes and improvements

made since then and was able to state with confidence that the problem would not recur.

Because the news photographers and TV cameramen would have found nothing very photogenic about allocation charts and tables, and lists of names, some of the City's new snow-fighting equipment was put on display for the occasion. In other words, for the results of urban systems analysis to be published in the right journals—The New York Times (14) and the Post (13)—the skills of a public relations expert in the City Hall Press Office were indispensable.

The city's new Snow Emergency Plan went into effect. Mayor Lindsay was re-elected. (No causal relationship is implied.) A report documenting the work was finally written and issued (16).

In the ensuing four years only one storm represented any sort of practical test of the system, an 8″ storm on a holiday, January 1, 1971. Everything went smoothly and the city was cleaned up within a few hours, with credit properly going to the Mayor, the Department of Sanitation, and the new plan.

References

1. Barton-Aschman Associates, "A Program for Improving Winter Street Maintenance in the City of Chicago", Chicago, Illinois, November, 1967.
2. City Manager, Hartford, Conn., *Snow Watch, Snow Warning, Snow Emergency*, Winter, 1968-69.
3. Dept. of Public Utilities, St. Louis, Mo., *Snow and Ice Control Procedure*, 1968.
4. Dept. of Public Works, Detroit, Mich., *Snow and Ice Control Operation*, 1967.
5. Dept. of Public Works, Minneapolis, Minn., *Snow Removal Equipment and Procedures*, 1968.
6. Dept. of Sanitation, New York, N. Y., *Snow Removal Manual*, October, 1966.
7. ——, "Preparation: Key to Snow Removal", *Sweep*, N. Y. C. Dept. of Sanitation, Winter, 1964.
8. Dept. of Streets, Burlington, Vt., *Snow Removal*, 1968.
9. Fenton, R., "Snow and Ice: Control and Removal", in *Street Cleaning Practice*, Amer. Public Works Assoc., Chicago, Ill., 1959.
10. Lennon, J. T., "Cost Analysis of Snow and Ice Control Operations", presented at Public Works Congress and Equipment Show, Boston, Mass., October, 1967.
11. Lockwood, R. K., "Snow Removal and Ice Control in Urban Areas", in *Research Project No. 114, Vol. II*, Amer. Public Works Assoc., Chicago, Ill., June, 1966.
12. National Research Council, *Manual on Snow Removal and Ice Control in Urban Areas*, Ottawa, Can., November, 1967.
13. New York Post, "Let it Snow! Mayor Says City is Ready", October 23, 1969.
14. New York Times, "Mayor Pledges New Equipment Will Keep Queens Free of Snow", October 24, 1969.
15. O'Connell, M. P., "Loading and Transporting Snow", presented ah Eighth Ann. North American Snow Conference, Amer. Public Works Assoc., Cincinnati, O., April, 1968.
16. Savas, E. S., *Planning for Snow Emergencies*, City of New York, Office of the Mayor, 1969, 79 p.